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INVESTIGATIONS CONCERNING YAWS

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The following studies of yaws, of which this paper is the first, are based upon experience in the treatment of the disease in the Dominican Republic, in the West Indies and upon investigations conducted at Parañaque and Las Piñas in the suburbs of Manila, Philippine Islands.

In the Dominican Republic, the major portion of the work was conducted in a field camp in a rather isolated section, inhabited for the most part by a somewhat primitive people. During the summer of 1920, in the course of two months, approximately three hundred fifty cases of yaws in the granulomatous stage were treated intravenously with neosalvarsan; these cases as well as those received in the later stages have already been reported.(2) Toward the close of the summer, the work was extended to another district of Santo Domingo in which two hundred active cases of yaws were treated by intramuscular injection of neosalvarsan.

The successful utilization of neosalvarsan under strictly field conditions in Santo Domingo raised the question of the feasibility of controlling or even eradicating yaws by treatment of infected individuals. In order to carry out field work intelligently, it seemed clear that certain preliminary investigations were

essential. Accordingly the study of yaws was continued, with the object of giving special attention to the features bearing upon the problem of its control by public-health measures. Through the courtesy of the Philippine Health Service a temporary dispensary was opened at Parañaque, near Manila, a district the inhabitants of which have been from time immemorial constantly infected with yaws. The patients were under the immediate care of Dr. Perpetuo Gutierrez, and the observations of clinical interest have been described by him.(1)

There are several attractive problems in the immunology of yaws. The behavior of the Wassermann reaction has not been thoroughly investigated; it is a subject of considerable interest, both from a serological point of view and on account of its practical importance. The reinoculation of yaws patients with the virus of yaws requires further investigation. From the standpoint of both the individual and the public it is very important to know whether spontaneous infection that has been cured by salvarsan affords any protection against reinfection. The investigation of the Wassermann reaction and the behavior of yaws patients upon reinoculation with yaws form the basis of the second and third papers of this series.

From the standpoint of field work, the choice of treatment and the method of administering salvarsan assume aspects which are very different from the conditions that obtain in standard hospital practice. This subject, together with other features of yaws that are of interest in the field of public health, will be considered in the fourth paper of this series.

The fifth paper deals with some problems in the histology of yaws which have been cleared up by Doctor Goodpasture during these investigations.

In the last paper of this series a brief discussion is presented concerning the possible control or even the eradication of yaws.

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THE EFFECT OF TREATMENT ON THE WASSERMANN REACTION IN YAWS

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At the yaws clinic established in Parañaque, near Manila, the Wassermann reaction was performed with sera, obtained before treatment, from 45 patients presenting active cutaneous lesions of this disease. Complete fixation of complement occurred in each instance, or in 100 per cent.

This result is in accord with the experience of many previous workers. Baermann and Wetter(1) tested the serum of 38 untreated cases of yaws rich in lesions and found 100 per cent positive. Schüffner(7) also reported 100 per cent positive in 38 similar cases.

Recently Moss and Bigelow(6) recorded briefly the results of the Wassermann test in 91 cases, at Santo Domingo. They found reaction strongly positive in 78 cases, moderately positive in 4, weakly in 1, and negative in 8. The negative results were obtained only in the late secondary and tertiary stages, or in patients who had no active lesions but who gave a history of yaws. These investigators subsequently also found 100 per cent positive reactions in the early stage of the disease.

From such reports it is evident that one may expect to find in the early eruptive stage of yaws, as in the florid secondary stage of syphilis,(5) a positive Wassermann reaction in 100 per cent of cases; consequently, the test offers no aid in differential diagnosis of the two diseases.

However, the constancy of positive reaction in the early stage of yaws suggests that the test should throw some light on the extent of treatment necessary, as it has done in syphilis. This phase of the subject has received scarcely any attention, although it is obviously of utmost importance, because efforts to eradicate the disease would necessitate treating hundreds of patients in endemic foci usually under field conditions where adequate observation over long periods of time would be next to im-

possible. The public-health officer under these circumstances is confronted with the question whether treatment may be discontinued, when a clinical cure is effected, without danger of an undue percentage of recurrences, and it may be properly asked whether the Wassermann test can be of any service in reaching an answer to this question.

With such problems in mind several cases in the acute secondary stage of yaws were investigated with reference to the complement-binding strength of titrated sera by means of the Wassermann reaction before treatment and clinical cure, and at intervals afterward, and where possible until they became negative.

Only one satisfactory observation bearing on the duration of the Wassermann reaction after treatment was found; namely, the single case, reported by Shamberg and Klauder,(8) of an American soldier who contracted the disease in France. The test was frequently repeated over a period of six months, during which time the patient received three intravenous injections of neosalvarsan, 0.9 gram each. At the end of two months the reaction had begun to weaken, and after six months was negative with alcoholic extract of syphilitic liver, acetone insoluble antigen, and almost so with cholesterized antigen. No one apparently has measured the complement-binding strength of titrated sera from yaws patients either before or after treatment.

Twenty-three young Filipinos, all presenting fresh cutaneous yaws, were selected for study. On twelve of these it has been possible to repeat the Wassermann test at intervals over a period of several months.

METHOD

The Wassermann test was performed according to the details described by Hinton.(4) In the hæmolytic system two units of antisheep amboceptor, 0.5 cubic centimeter of a 5 per cent suspension of washed sheep-cells brought to the original volume of whole blood, and two units of guinea-pig serum complement were used in each test. The uniformity of sheep-cell suspension was controlled by a color standard, and sera from several pigs were pooled to obtain a complement of uniform strength. A maximum of 0.1 cubic centimeter of patient's heated serum was used in each test and a control of 0.2 cubic centimeter, for anticomplementary action. Only one antigen was employed, instead of three as practiced by Hinton. Most of the tests were made with cholesterinized alcoholic extract of guinea-pig's heart used in

doses of 0.1 cubic centimeter of a 1 plus 4 dilution. This antigen was not anticomplementary with twice the amount used in the test. A few tests were made with a cholesterinized alcoholic extract of beef heart in doses of 0.2 cubic centimeter of a 1 plus 4 dilution of approximately the same antigenic strength as the former antigen, and showing no inhibition of hæmolysis with twice the amount used in each test. The test was controlled by the use of normal and syphilitic sera.

The results of tests on the twenty-three sera[1] titrated before treatment to determine the minimal fixing dose—that is, the least amount of serum necessary to prevent complete hæmolysis—are tabulated in Table 1.

TABLE 1.—*Wassermann reaction with titrated serum from yaws.*

Cases of active yaws.	Minimal fixing dose of serum. cc.
[a] 1	0.1
4	0.01
6	0.005
4	0.004
5	0.003
3	0.002
0	0.001
Total 23	

[a] This case gave a 3 + reaction.

It is to be observed that approximately half of these sera have a minimal fixing dose of 0.004 cubic centimeter or less, and in only one is 0.1 cubic centimeter necessary for a positive reaction. The serum of a yaws patient in this stage of the disease is evidently strong in its complement-binding power with lipoidal antigens, and in this respect compares favorably with sera from untreated syphilis. Serum from three untreated cases of syphilis was titrated for comparison, the minimal fixing dose being 0.002, 0.1, and 0.01 cubic centimeter, respectively.

So far as the results go, it can safely be said that the maximum complement-binding strength of serum from early secondary yaws is equal in the Wassermann test to the maximum found in syphilis.

Twelve of the twenty-three cases of yaws were observed over a period of several months. The Wassermann reaction was

[1] In two of these cases Wassermann reaction was performed on spinal fluid and found negative.

performed and the minimal fixing dose of serum established a second time, shortly after clinical cure, and again some months later when several of them had become negative. Table 2 gives a summary of these cases and the clinical results of treatment.

In Table 3 are tabulated the results of the test before treatment on these twelve cases and the effect of treatment on the complement-binding strength at intervals afterward.

It is evident from Table 3 that, during the first month after treatment, there is a rapid fall in complement-binding strength with lipoidal antigen, then a more-gradual weakening over a period of several months until in the majority of cases the reaction becomes negative with 0.1 cubic centimeter, or the standard dose of serum. Several of these cases received a second injection of neosalvarsan but always in about two weeks after the first, so that the initial rapid diminution in strength of the serum in the first month may have been due to the repeated treatment. Nevertheless, the Wassermann reaction with 0.1 cubic centimeter of serum was still strongly positive a month or more after the first injection, and two or three weeks after clinical cure in several instances, and in seven of the twelve cases was still positive five months after the first injection. The fact is established that clinical cure is not coincident with disappearance of positive reaction; but, in our studies, the serum gradually, within a period of several months, became negative in seven of the twelve cases and much weaker in the others, following clinical cure and without further treatment.

The rapidity with which a positive serum becomes negative in a general way seems to depend on the degree of complement-fixing strength with lipoidal antigens present in a particular serum before treatment, although there are exceptions to this even in our small series. If we compare the six weakest sera with the six strongest we find an average minimal fixing dose for the former of 0.0071 cubic centimeter, and for the latter 0.0026. One month after treatment the corresponding figures are 0.053 and 0.023. In five months we find in the first group three negative sera and three weakly fixing sera, and in the second group two negative, two strongly positive, and two weakly fixing.

We judge from this behavior of the Wassermann reaction that a positive test following clinical cure does not necessarily indicate persistence of the infection, but may rather be due to a gradual process of elimination by the body of substances upon which a positive reaction depends; and, since the majority of

TABLE 2.—*Treatment of twelve cases of yaws with neosalvarsan.*

Case.	Sex.	Age.	Duration of yaws.		Present lesions.		Treatment.					
					Mother yaw.	Secondary lesions.	First injection.		Result.	Second injection.		Result.
		Yrs.	*Yrs.*	*mos.*				*g.*			*g.*	
1	M	7	1	0	None	Hands, head, back, and left foot.	September 12, 1921	0.45	September 21, 1921, healing.	September 21, 1921	0.45	February 17, 1922, cured.
2	F	5	1	0	(?)	Face, body	do	0.3		September 27, 1921	0.3	October 31, 1921, cured.
3	F	12	0	3	Left arm	Face, neck, axilla	September 19, 1921	0.45	September 29, 1921. Secondaries dry; primary not healed.	October 3, 1921	0.45	October 3, 1921, almost cured.
4	F	18	0	9	None	Face, body	September 12, 1921	0.6	September 21, 1921, lesions dry.	September 29, 1921	0.6	October 29, 1921, cured.
5	F	11	2	0	do	Mouth, thigh, bones of fingers, and feet.	do	0.45	September 21, 1921, skin lesions dry.	October 27, 1921	0.3	Skin lesions cured.
6	F	12	1	0	do	Face, thigh, perineum.	September 19, 1921	0.3	October 3, 1921, skin lesions dry.	October 3, 1921	0.45	October 27, 1921, cured.
7	M	7	2	0	do	Head, body	September 22, 1921	0.45	October 3, 1921, cured.	do	0.3	
8	F	14	0	9	Knee	Head, back, axilla, legs.	September 19, 1921	0.6	do	do	0.6	
9	M	3	0	3	Forehead	Face, body, legs	do	0.3	October 3, 1921, almost cured.	do	0.3	October 27, 1921, cured.
10	M	7	2	0	None	Face, perineum, legs.	September 12, 1921	0.3	September 29, 1921, cured.			
11	M	14	10 (?)	0	do	Face, body	do	0.45	September 29, 1921, nearly cured.	September 27, 1921	0.45	October 12, 1921, cured.
12	M	11	1	0	do	Perineum	do	0.45	September 29, 1921, lesions dry.	October 3, 1921	0.45	Cured.

TABLE 3.—*The Wassermann reaction with titrated yaws serum before and at intervals after treatment with neosalvarsan.*

Case No.	Before treatment. Serum dilutions in cubic centimeters.							After first injection. Serum in cubic centimeters.					Days.	Serum in cubic centimeters.			Days.	Serum in cubic centimeters.		Days.
	0.1	0.01	0.005	0.004	0.003	0.002	0.001	0.1	0.01	0.005	0.004	0.003		0.1	0.01	0.005		0.1	0.01	
1	4	4	3	2	1	0	0	4	1	0	0	0	42	0	0	0	158	----	----	----
2	4	4	4	4	3	2	0	4	1	0	0	0	49	1	0	0	158	0	0	246
3	4	3	0	0	0	0	0	3	0	0	0	0	35	0	0	0	151	----	----	----
4	4	4	3	2	1	0	0	4	0	0	0	0	49	0	0	0	158	----	----	----
5	4	4	3	2	0	0	0	4	3	0	0	0	45	3	0	0	171	0	0	246
6	4	4	4	4	4	3	0	4	3	2	1	0	24	4	0	0	164	2	0	239
7	4	3	1	0	0	0	0	4	0	0	0	0	21	0	0	0	161	----	----	----
8	4	4	4	4	4	3	0	4	4	4	3	0	24	4	0	0	164	----	----	----
9	4	2	0	0	0	0	0	4	0	0	0	0	24	0	0	0	164	----	----	----
10	4	4	3	1	0	0	0	4	4	2	1	0	35	3	2	0	171	4	0	246
11	4	2	0	0	0	0	0	4	2	0	0	0	35	2	0	0	171	2	0	246
12	4	4	3	1	0	0	0	4	4	4	3	0	31	2	0	0	178	2	0	253

[4 = no hæmolysis, 3 = faintest hæmolysis, 2 = strong hæmolysis, 1 = almost complete hæmolysis, 0 = complete hæmolysis. The time each test was performed is recorded in the number of days after the first injection of neosalvarsan.]

sera will spontaneously become negative in the course of a few months, it is not necessary in treating the disease on a large scale to continue therapy until a negative reaction is accomplished. A better guide would seem to be the complete healing of all clinical manifestation of activity of the disease.

Bearing upon this point and supporting the above conclusion is the reported alteration of the Wassermann reaction following treatment of yaws with mercury.

Baermann and Wetter state that the reaction became negative in about 50 per cent of cases of yaws following a single course of treatment with mercury. In contrast to syphilis they noted frequently a diminution in strength of the reaction or a complete alteration after even two or three injections of the salicylate. The reaction in their experience seemed to remain negative in yaws after treatment longer than in syphilis. Although these authors do not state the exact time in which a reversal in reaction took place they probably mean within a few weeks. This is not the case following injections of neosalvarsan, although this drug is incomparably more effective than mercury in the treatment of yaws. Evidently no great clinical importance can be attached to reported changes in the Wassermann reaction following mercury therapy.

In order to observe the effect of mercury on the cutaneous lesions of yaws and on the Wassermann reaction we made observations on four acute cases, all of whom were Filipinos of about the same age, with abundant fresh secondary lesions. The following protocol of one of these cases will serve to illustrate this group. The treatment given each of these cases was the same and in each case it proved equally ineffective.

The patient was admitted to the Philippine General Hospital with early secondary lesions of yaws. He received three intramuscular injections of 0.25 cubic centimeter succinamide of mercury (1 per cent) at four-day intervals, four 0.5 cubic centimeter injections at three-day intervals, two 1 cubic centimeter injections at two-day intervals, and two 0.5 cubic centimeter injections of mercury salicylate with an interval of seven days between doses. The period of treatment was from September 24 to October 31. There was no noticeable effect on the skin lesions and 0.45 gram of neosalvarsan was given intravenously and was followed by immediate healing.

Table 4 presents the results of Wassermann tests performed before treatment, and twice during treatment.

While a moderate initial diminution in complement-fixing strength is evident in Table 4, after five weeks of treatment no

further weakening is noted, and clinically, notwithstanding the diminished fixing strength of serum, the lesions continued active throughout the period of treatment. Following a single injection of neosalvarsan the lesions rapidly healed.

TABLE 4.—*Wassermann reaction in cases of yaws treated with mercury.*

Case No.	Serum titration in cubic centimeters.													
	September 22, before treatment.						October 13.				October 31.			
	0.1	0.01	0.005	0.004	0.003	0.002	0.1	0.01	0.005	0.004	0.1	0.01	0.005	0.004
1	4	4	3	2	1	0	4	3	0	0	4	3	0	0
2	4	3	1	0	0	0	4	0	0	0	4	0	0	0
3	4	3	2	1	0	0	4	1	0	0				
4	4	4	3	3	1	0	4	3	1	0	4	4	1	0

After intravenous injection of neosalvarsan a preliminary relatively rapid drop in the fixing strength of serum was also noted and, in order to determine whether the immediate presence of the drug in the serum was partially responsible for this, the serum of a single case was titrated before and immediately after intravenous injection. The results of the Wassermann reaction with the two samples were identical.

The supposition seems justifiable that the gradual diminution in complement-fixing strength of serum over a period of several months following an initial effective treatment, with an eventual return to a negative reaction, indicates that the patient has been completely cured. In syphilis the Wassermann reaction may readily become negative during treatment only to return when treatment is discontinued. Should any infection remain we might expect persistence of positive reaction if not increase in fixing strength of the serum. There is evidence, presented by a large proportion of latent or chronic cases of yaws, that a positive reaction may be present years after the acute manifestations of the disease have subsided. Schüffner reports 85 per cent positive in chronic late yaws and 58 per cent in the latent type. We tested the serum of six adults who presented no obvious evidences of the disease but gave a history of yaws in childhood, and found two, or 33 per cent, positive.

Since the Wassermann reaction has become negative in the course of five or six months after treatment in the majority of cases, the indications are that, in the event that reaction continues positive for a year or more, the treatment has been insufficient and should be repeated even though no recurrence be evident. Provided treatment at first is continued until there is a complete healing of superficial lesions the number of such cases probably would be exceedingly small.

At the clinic in Parañaque several children with chronic indolent ulcers, especially of the feet and ankles, presented themselves for treatment, some of them giving a history of yaws in the past. Sera from six such individuals in whom the diagnosis of yaws was questionable, though four gave a history of yaws, were strongly positive. No doubt many ulcers of this kind are based upon an original infection with *Treponema pertenue* and, in an attempted eradication of the disease from an endemic focus, they are an important factor.

Castellani (3) was able to demonstrate specific fixation of complement with an antigen prepared from yaws papules containing *Treponema pertenue* and serum from a monkey that had been successfully inoculated with yaws and afterwards treated at intervals with subcutaneous inoculations of yaws material. This fact encouraged the hope that by this means, using serum from patients, yaws and syphilis might be differentiated. Bowman (2) later reported positive fixation with such antigen and sera from yaws patients, and negative tests with sera from syphilitics, but the tabulation of his results indicates that the reaction was not entirely specific. We repeated the test with an antigen prepared from an early yaw containing treponemata, according to the method used by Bowman, using otherwise the technic employed for the Wassermann reaction. Two syphilitic sera and two yaws sera, each strongly positive with cholesterinized antigen, and two normal sera showed no fixation of complement. In view of the close similarity of the Wassermann reaction in the two diseases, it seems extremely doubtful that an antigen will ever be prepared sufficiently specific for practical purposes in differentiating yaws and syphilis.

DISCUSSION

A positive Wassermann reaction in the Tropics does not bear the same diagnostic significance that it does in the Temperate Zone. It is present in a large proportion of cases of leprosy free

of syphilis, and has been frequently reported in malaria, but its constancy in yaws is very confusing from the standpoint of differential diagnosis. In a district infested with yaws the reaction is of no value in diagnosing syphilis. However, the treatment of the two diseases being the same, the reaction is of great value from the standpoint of indicating the need of salvarsan therapy. While a positive test in yaws, as in syphilis, presupposes infection, a different estimate must be placed on the behavior of the reaction following treatment with neosalvarsan. This is due largely to the fact that yaws is ordinarily much more amenable to treatment and a few injections not infrequently effect a complete cure, although the Wassermann reaction may remain positive for several months afterward, gradually becoming weaker, however, and eventually negative, without further injection of neosalvarsan. It is unnecessary therefore to continue treatment until a negative reaction is obtained. In syphilis, on the other hand, the test often becomes negative under intensive treatment only to become positive again when injections are discontinued. Neither yaws nor syphilis can be regarded as completely cured so long as a positive test persists, but in yaws a cure may be presumed on the disappearance of clinical evidence of activity, and no further treatment is necessary unless the reaction persists or becomes stronger after the lapse of many months.

Although in the case reported by Shamberg and Klauder the Wassermann reaction became negative with alcoholic extract of syphilitic liver and acetone insoluble antigen and 1 + as recorded in their chart, and 2 + as stated in the text, in a scheme in which 4 + indicated complete fixation, the authors nevertheless considered the infection still present. Evidently they were applying to yaws the same significance which experience has taught attaches to a persistence of a positive reaction in syphilis. Interpreted in the light of our results, one is justified in assuming that their case was cured and that in a few months the reaction would have become negative spontaneously.

In the absence of clinical manifestation of activity a negative Wassermann test must be the final criterion of a cure in yaws. Consequently, the reaction should be used to establish the efficacy of any treatment of yaws such as with tartar emetic as used by Castellani; and in latent yaws, where clinical evidences are slight, it should be of utmost importance in determining the effect of treatment with neosalvarsan or other methods.

From the standpoint of diagnosis, the Wassermann reaction is of value in recognizing latent yaws and in differentiating tropical ulcers that may be benefited by neosalvarsan from those that have no relation to either syphilis or yaws.

SUMMARY

1. The Wassermann test was strongly positive in 100 per cent of 45 patients presenting active cutaneous lesions of yaws.

2. Complement-binding strength of titrated serum from yaws is equal to the maximum strength of syphilitic serum.

3. Following the clinical cure of yaws by intravenous injection of neosalvarsan the Wassermann reaction remained positive for many months, gradually weakened, and became negative in seven of twelve cases within six months after treatment.

4. Treatment of yaws in the early secondary stage with mercury caused no noticeable improvement in the lesions. The Wassermann reaction showed an initial slight weakening in the titre, then remained constant and strongly positive.

5. An antigen prepared from an early yaw containing treponemata did not fix complement with sera from yaws patients that were strongly positive with the usual cholesterinized antigen.

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IMMUNITY IN YAWS

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TWO PLATES

The question of immunity in yaws has received scanty attention, notwithstanding its clinical importance and its theoretical interest. The experimental data and even the clinical observations are extremely meager.

The clinical evidence bearing upon the immunology of yaws is complicated by wide variation in opinion concerning the spontaneous course of the natural infection. Since the introduction of salvarsan therapy the opportunity no longer exists of following individual patients through the entire course of the disease. The clinical picture must be built up from the composite study of many individual cases seen at varying stages of the infection. Some observers question the existence of a tertiary stage, believing that the disease ends with the disappearance of the secondary eruption. Others lean decidedly toward the view that, after the secondary stage, the infection lies dormant or continues with tertiary manifestations practically throughout life.

The evidence of tertiary manifestations rests chiefly upon clinical grounds and not upon any exact demonstration in the laboratory. Perhaps the clearest indication of tertiary involvement is to be found in the bone lesions. These develop not uncommonly in children during a typical attack of yaws. The Wassermann reaction is positive, and the symptoms yield to salvarsan therapy. The possibility must be considered of a double infection of syphilis and yaws. However, in a community where syphilis is uncommon, and when the patient and his family show no taint of the disease, a syphilitic etiology of these bone lesions is practically excluded.

The question of establishing spontaneous cure presents some difficulties. On several occasions, children showing a typical infection of yaws were brought to the clinic at Parañaque by their parents who stated clearly that they themselves had had yaws in childhood and recovered spontaneously without any sequelæ. They had full confidence in their immunity and handled their children without fear of reinfection. The Wassermann reaction of six of these adults was taken and found to be negative in all but two instances.

Briefly, we feel convinced that in a large number of cases the disease terminates spontaneously at the end of the secondary stage, while in others the infection lies latent or proceeds to tertiary manifestations. There are no data available from which even approximate percentages can be estimated. Moreover, it is likely that the late manifestations of the disease vary somewhat in different localities in the Tropics. In Santo Domingo, large numbers of extremely bad cases of clavos were seen. In Parañaque some effort was required to find clavos cases, and the lesions were not extensive.

The available clinical evidence indicates that the majority of patients, after passing through the secondary stage, are not likely in later years to experience a return of the typical granulomatous eruption. Immunologically, distinction must be made between a sterilizing immunity and a refractory latent infection preventing reinfection. The treponemata of yaws may behave, on the one hand, like the spirochætes of relapsing fever which many believe produce true immunity; or, on the other hand, they may behave like the treponemata of syphilis.

These points have been investigated by the reinoculation of yaws in one group of patients during the secondary stage of the disease, and in another group some months after treatment with neosalvarsan. The dosage was regulated according to the table in the fourth paper of this series. These patients coöperated cheerfully and faithfully in all of this work, and for no recompense except the treatment with neosalvarsan which they received.

REINOCULATION OF YAWS PATIENTS DURING THE SECONDARY STAGE

It was assumed, on clinical grounds, that patients in the primary or the early secondary stage of the disease could be readily reinfected with yaws. The secondary lesions do not differ from the primary ones in any respect. Successive crops appear from time to time in such patients for a period of many

months, developing usually metastatically, though occasionally perhaps by direct accidental inoculation.

The material for the first inoculations was secured by removing the yellow crust from a well-developed yaw and scraping the surface firmly with a scalpel. The exudate thus obtained always contained a moderate amount of blood, and no precautions were taken to insure the removal of visible pieces of tissue. Smears of this material were subsequently stained by Giemsa's method. Usually treponemata were very scanty. Observers frequently speak of the very abundant spirochætes seen in smears from yaws nodules. We have not found spirochætes in large number except secondary invaders, distinct from the causative treponema. This material was reinoculated immediately in an incision through the skin, made sufficiently deep to cause a slight oozing of blood. The skin over the deltoid muscle was selected for the site of inoculation, since this area is not ordinarily involved spontaneously. The work was conducted under dispensary conditions, and it was not feasible to make observations oftener than at intervals of one week. The details are as follows:

In the first case the disease was of two months' duration at the time of reinoculation, the mother yaw being present and active. There was also a generalized papular eruption over the trunk and the lower extremities. The inoculations were made in three incisions. A week later they had healed completely. Observations were continued for a period of six weeks, and no changes occurred at the site of inoculation. In the meantime, however, typical multiple granulomata developed elsewhere over the body. The patient was given neosalvarsan.

The second case had developed a mother yaw five months previously and now showed five secondary granulomata. Three incisions in which the inoculations were made healed promptly and remained entirely negative during the six weeks' period of observation. Treatment with neosalvarsan was commenced.

In the third case the disease was of four months' duration, the mother yaw being present. One month after its appearance, the patient was vaccinated against smallpox and a typical granuloma developed at the site of this vaccination. Numerous papules also appeared over the face and the body; several developed into typical granulomata. Material from one of these was reinoculated into three incisions of the skin over the deltoid. The incisions healed promptly; during the next six weeks some additional granulomata developed but none appeared

at the site of inoculation. Treatment with neosalvarsan was commenced.

Some of the earlier observers report the successful inoculation of yaws in normal individuals with the production of a generalized eruption but without the development of a primary lesion at the site of inoculation. Usually, however, a mother yaw develops just as in the spontaneous disease. Paulet(9) inoculated 14 normal men successfully with yaws and in 10 a local lesion developed. Charlouis(4) inoculated 32 Chinese prisoners, in 28 of whom yaws developed; in each case a local lesion appeared at the point of inoculation. Nicholle(8) inoculated 8 men successfully but in 3 no primary lesion developed.

There is no evidence that any of the reinoculations of our three cases was successful. Another group of four patients was selected and inoculated in the same manner. These patients were well advanced in the secondary stage. Indeed, the onset of the disease had occurred so long ago that it was not possible to determine with certainty even the approximate date. In all of these cases, however, the secondary stage had existed for at least eight months. The inoculations were made in the same manner as in the three cases mentioned, two incisions being made in the skin over the deltoid. The incisions healed promptly and no fresh granulomata developed elsewhere over the body. Two weeks later three patients of the second group were reinoculated on the opposite arm. Care was taken to implant a small piece of tissue from the yaws granuloma. A superficial incision was made in the patient's skin and the piece of yaws tissue was caught in a nick in the cut edge. The incision soon filled with blood which clotted firmly over the implanted tissue. Subcutaneous implantation was avoided on account of the possibility of secondary infection. In two of these patients the result was entirely negative. In the third, one week after inoculation, the upper incision had healed completely. A slight but distinctly elevated ridge had formed along the entire line of the lower incision 0.5 centimeter in length. At the end of the second week a small round lesion, 3 millimeters in diameter and 2 millimeters in height, had developed. One week later, this granuloma had increased a little in size and the skin immediately surrounding it was slightly hyperæmic. At this time, it seemed that the lesion was commencing to grow rapidly. However, one week later the granuloma was distinctly smaller and the hyperæmic zone had disappeared. A photograph was

taken (Plate 1, fig. 1) showing this lesion and also, in poor focus, some spontaneous granulomata on the neck. Treatment with neosalvarsan was commenced at this time.

Two other cases of yaws of a very different type were reinoculated. Both of these were cases of clavos who had recovered spontaneously from the granulomatous stage many years ago. It seemed desirable to test experimentally the possibility of producing a typical granuloma in patients during the late stage of the disease.

Both of these patients gave clear intelligent histories. One had typical yaws twenty years ago and now has thickened and excoriated skin over the soles of both feet and similar lesions in the palm of one hand. When the patient is at work there is moderately severe pain. The other patient had a granulomatous eruption of yaws of three years' duration ending ten years ago. He now has moderate thickening and excoriation of the skin over the sole of one foot only. There is practically no pain. Neither of these men has had any return of the granulomata. The Wassermann reaction was performed and showed complete fixation in both cases. There was nothing in the history or examination of these patients suggestive of syphilitic infection.

Implantation of yaws tissue was made in two incisions in the skin over the deltoid in each patient. One week later a papillary eruption was developing rapidly at the site of each implant in both patients. At the end of the second week, however, the reactions had almost completely subsided, no suitable material being available even for microscopic study. The observations were discontinued and neosalvarsan injections were commenced for the treatment of clavos.

INOCULATION OF PATIENTS WITH YAWS AFTER TREATMENT WITH NEOSALVARSAN

A group of four cases of yaws in the secondary stage received treatment with neosalvarsan. Nearly six months later, small pieces of yaws tissue were implanted in an incision in the skin. Observations were continued for four and one-half months. Some instructive results were obtained. In one patient, a typical granuloma developed at the site of inoculation and progressed rapidly; with the appearance of early secondary lesions, neosalvarsan was given. In the other three patients, small granulomata appeared after a short time at the site of

inoculation and then disappeared spontaneously in two of these cases. The details of these four cases are briefly as follows:

In the first patient, seen September 19, 1921, the mother yaw appeared on the forehead and was first noticed three months ago. It is now about the size of a peso (about 3.5 centimeters.) The secondary lesions appeared one month after the mother yaw. At present there are numerous granulomata over the forehead, the neck, in the right axilla, over the chest, the abdomen, and both legs, as well as numerous small papules. Recently there has been pain in the bones. One injection of neosalvarsan was given. The pain in the bones disappeared, and the lesions healed so rapidly that the patient did not return to the dispensary until October 3. At this time the granulomata had almost entirely disappeared. A second injection of neosalvarsan was given, and two weeks later there was no discernible evidence of any active lesion.

The Wassermann reaction on September 19 showed complete fixation with 0.1 cubic centimeter of patient's serum. On October 12 the titre had not changed, 0.1 cubic centimeter giving complete fixation. On March 2, 1922, the reaction was negative.

On March 9, 1922, this patient was reinoculated with yaws, two incisions of the skin being made about 1 centimeter apart. A small piece of tissue was excised from the surface of an active yaw from a patient in the early secondary stage and was used for the inoculation of this group of 4 patients. One week later (March 16) these incisions had healed with very slight elevation of the skin. At the end of the second week (March 23) both incisions showed a very distinct elevation. At the end of the third week (March 30) characteristic granulomata had developed at each of the two sites of inoculation and they were surrounded by a bright red areola. The appearance at this date is shown in the accompanying photograph (Plate 1, fig. 2). Blood was taken for a Wassermann test, and the reaction was negative. A week later (April 6) the two granulomata had coalesced into one. At the end of the fifth week (April 12) there were numerous, minute, discrete papules over the body surrounded by a hyperæmic area. These were presumably the beginning of the secondary lesions. There was no sign of regression in the mother yaw. One injection of neosalvarsan was given, and the lesions disappeared promptly.

The second patient was seen first on September 12, 1921. He contracted yaws "much more" than one year ago. The scar of the mother yaw could still be seen in the right popliteal space.

There have been successive crops of secondary lesions; the scars of several can still be seen plainly on the chest and the abdomen. Granulomata have persisted continuously around the anus. The first injection of neosalvarsan was given at this time. September 21 the lesions have almost completely dried. A second injection of neosalvarsan was given. October 3 the patient appeared clinically cured; nevertheless, a third injection of neosalvarsan was given.

The Wassermann reaction on September 12 showed complete fixation with 0.01 cubic centimeter of serum in a system designed for the use of 0.1 cubic centimeter of patient's serum. On October 12, 0.005 cubic centimeter gave complete fixation. On March 9, 1922, 0.1 cubic centimeter gave partial fixation and 0.01 allowed complete hæmolysis. On this date, minute pieces of yaws tissue were implanted in incisions of the skin about 0.5 centimeter apart. The patient was not seen again until two weeks later. At this time both incisions showed distinct elevation. At the end of the third week (March 30) the elevated ridge of epithelium along the upper incision was drying up. At the lower incision there was a small dry papule. The appearance is shown in the accompanying photograph (Plate 1, fig. 3). The Wassermann reaction taken at this time showed the same titre as on March 9. At the end of the fourth week these epithelial lesions had desquamated completely, leaving only the barely discernible linear scar of the incision. On May 16, the Wassermann reaction still showed the same titre as on March 9 and March 30. No more Wassermann tests were taken; a final clinical observation was made July 20, there being no suggestion of any lesions of the skin.

The third patient was seen September 22, 1921. The mother yaw appeared almost two years ago, and the patient is certain that it healed more than one year ago. There are numerous evidences of healed secondary lesions on various parts of the body. There is one cluster of granulomata on the back of the neck now, but the lesions are dry and show signs of regression. For three months the patient has noticed pain in the bones of the hands and the feet. The first injection of neosalvarsan was given at this time. October 3 the pain in the bones has disappeared, and the skin lesions have cleared up completely. A second injection of neosalvarsan was given.

The Wassermann reaction on September 22 showed complete fixation with 0.1 cubic centimeter of serum and almost complete fixation with 0.01 cubic centimeter. On October 12, 0.1 cubic

centimeter gave complete fixation, but complete hæmolysis occurred with 0.01 cubic centimeter of serum. On March 2 the reaction was negative with 0.1 cubic centimeter of serum.

On March 9, 1922, tissue from a yaw was implanted in two incisions of the skin about 0.75 centimeter apart. A week later (March 16) these incisions showed nothing more than ordinary healing. At the end of the second week however (March 23) each of these incisions showed a broadened elevated ridge of epithelium. One week later (March 30) these lesions were beginning to dry and regress. They are illustrated in Plate 2, fig. 1. The Wassermann reaction at this time was negative. At the end of the fourth week (April 6) these small lesions had desquamated completely. The final observation was made on July 20.

The fourth and last case came to the dispensary on September 12, 1921. An active mother yaw was present on the left wrist. According to the history it appeared eight months ago. There are numerous secondary yaws over the forehead and neck, around the eyes and mouth, on the right hand and wrist, over the scrotum, in both popliteal spaces, and on the right ankle. Neosalvarsan was injected on this date. September 21 the skin lesions are only partially healed. A second injection of neosalvarsan was given which resulted in complete disappearance of the skin lesions.

The Wassermann reaction on September 12 showed complete fixation with 0.01 cubic centimeter of serum, and almost complete with 0.005 cubic centimeter. On October 24 complete fixation occurred with 0.1 cubic centimeter of serum, but hæmolysis was almost complete with 0.01 cubic centimeter. On February 17, 1922, the reaction was negative with 0.1 cubic centimeter of serum.

The inoculation with yaws was made on March 9, 1922, in two incisions about 1 centimeter apart. At the end of the first week (March 16) there was a slight suggestion of elevation of the epidermis along the line of healing. At the end of the second week (March 23) this elevation was definite, and a week later (March 30) at the lower incision a small definite granuloma had developed, 7 millimeters in its longest diameter and about 2 to 3 millimeters in height. It appeared rather inactive, as though spontaneous regression was about to set in. A photograph was taken (Plate 2, fig. 2) and the lesion excised for histological study. A section through this tissue shows a polymorphonuclear

leucocytic infiltration of the epithelium. The epithelial layer is very thin in the center and is covered by leucocytic exudate. On either side, the epidermis is slightly thickened and filled with fluid and cellular exudate. The superficial layer of corium is acutely inflamed, showing dilatation of capillaries, œdema, and polynuclear cell exudate. Below this there is a dense infiltration with large and small lymphocytes and a few plasma cells. There is also a mononuclear cell exudate about the sweat glands. The appearance is characteristic of yaws. A Levaditi preparation shows no treponema.

The other lesion developing at the upper incision was not disturbed, in order to determine whether it would regress spontaneously. The Wassermann reaction was practically negative. At the end of the fourth week (April 6) the lesion along the upper incision had disappeared completely. Primary healing had taken place along the line of excision of the granuloma removed for study; however, one month later, six small granulomata developed with some induration of the underlying tissue. These gradually coalesced into one large yaw. The appearance on May 25 is shown in the accompanying photograph (Plate 2, fig. 3). It was not pedunculated as might possibly be inferred from the illustration.

At this time there was no suggestion of any secondary lesions, and the primary yaw had begun to regress gradually. On June 20 an area representing almost one quarter of the yaw had practically healed along the upper edge of the yaw. Some weeks later, however, there was a slight extension of the yaw along its lower edge. The remainder of the body was entirely free from any lesions of the skin. On July 13, a little more than four months after inoculation, treatment with neosalvarsan was commenced.

On reinoculating these four cases with yaws the urine was tested for arsenic biologically, using *Penicilium brevicaule.* The results were negative, but the control tests were not entirely satisfactory. However, neoarsphenamine is excreted rather rapidly after intravenous injection. Moreover, the results in these cases could hardly be explained by incomplete excretion of arsenic.

TREATMENT WITH SERUM

In addition to these investigations on the effect of reinoculation, some observations were made on the supposed beneficial action of the serum of patients undergoing salvarsan treatment.

Alston(1) treated a small series of yaws cases in 1911 with salvarsan. The supply of the drug being limited, he tried the effect of injecting serum taken from cases of yaws several days after the injection of salvarsan. Pronounced improvement occurred and, what is more surprising, serum collected from the cases treated with serum produced beneficial results on injection into yaws patients. Such a striking phenomenon is of distinct interest immunologically. It is very suggestive in certain aspects of the occurrence in vivo of the d'Herrelle phenomenon.

Two papers were published by Alston. In the first, the striking improvement following the injection of serum was noted. In the second paper Alston stated that all of the cases treated with serum improved for two or three weeks. Thereafter they either remained stationary or became worse; but he expressed the belief that, if the injection of serum had been continued, the patients would probably have gone on to complete cure. These papers have been misquoted in the literature, the impression being given that actual cures were obtained. However, from the standpoint of immunology, striking improvement would be of great importance.

The details of Alston's work are as follows: Salvarsan (606) was given to adults in the secondary stage of yaws in full doses intramuscularly. Four to five days later, a cantharides blister was applied to two cases and the resulting serum was collected. This serum was injected (perhaps intramuscularly) in several yaws patients, in quantities of 16 cubic centimeters for the adult dose. Improvement was noted fully as rapidly as after salvarsan, changes being noticeable in some cases after sixteen hours.

A second group of yaws cases was injected with salvarsan, and serum collected from them produced rapid improvement when injected in yaws patients. The cases receiving serum were blistered with cantharides, and the resulting fluid was injected into two boys in a dosage of 8 cubic centimeters each. Improvement commenced promptly. Alston conducted several control experiments, the more-important results being that (*a*) blister fluid from normal persons and (*b*) from untreated yaws cases showed no beneficial effect, and (*c*) the heated serum from treated yaws cases was efficacious even after boiling. Rost(10) supplied the salvarsan for this work and observed the cases treated with serum. He confirms the striking improvement noted by Alston.

This work was repeated with the introduction, however, of some modifications. Neosalvarsan was injected intravenously, and serum was obtained by taking a specimen of the patient's blood several days later.

An adult yaws patient in the active secondary stage was injected with 0.75 gram neosalvarsan. Four days later blood was drawn by direct puncture from a vein of the arm. The specimen was kept on ice for three hours and the serum removed. Three patients with typical granulomata of yaws were injected. A child of 11 years of age received 20 cubic centimeters intramuscularly; another, 6 years old, received 10 cubic centimeters intravenously; and another, 4 years old, received 5 cubic centimeters intramuscularly. No improvement followed in the succeeding week. These patients were then injected with neosalvarsan and responded promptly.

A second adult patient with florid secondary yaws was given 0.6 gram neosalvarsan intravenously. Two days later, 200 cubic centimeters of blood were withdrawn and stored overnight on ice. Serum was injected into two patients showing active secondary lesions. One, 14 years old, received 20 cubic centimeters intravenously, but no improvement followed. The other, a child of 5 years, was given 12 cubic centimeters intramuscularly. Three days later some of the granulomata were slightly drier than at the time of injection. The change however was very slight and not greater than might occur spontaneously. Another injection was given intramuscularly of the serum, which had been stored on ice, using 12 cubic centimeters. No improvement followed. Both of these cases responded promptly to neosalvarsan.

Taking into full consideration the modifications we have introduced, it is difficult to explain the discrepancy between our results and those obtained by Alston.

DISCUSSION

The reinoculation of yaws patients before and after treatment with salvarsan appears to us to afford a valuable procedure for the study of immunity in this disease. The data recorded in this paper are rather meager, but the results are fairly clear-cut and at least serve as an outline of the various types of reaction that may be expected. The following interpretation is based upon the character of the reaction obtained and is entirely independent of the percentage of successful inoculations:

Untreated cases.—It is noteworthy that many failures followed the inoculation of scrapings from a yaw in patients during the secondary stage of the disease. This suggests that the secondary granulomata do not arise readily from accidental transference by the patient to abrasions in various parts of the body. Reinoculation during the primary stage of the disease might give a high percentage of "takes;" the results in the secondary stage are of more interest. The failures we obtained are in marked contrast to the results recorded by Charlouis. This observer in 1881 carried out a large series of a variety of human inoculations of fundamental interest and significance. The records are given with such brevity, however, that no analysis of the data is possible. Of four patients who were reinoculated, three developed papillomata. On reinoculating two of these patients, one was positive. Jeanselme and Angier(5) reinoculated a fully developed yaws patient four months after the onset and, again, five months later. The results were negative.

In our work, reinoculation in the late granulomatous stage resulted only once in the development of a lesion. The most striking characteristic of the experiment was the prompt spontaneous regression of the lesion. This seems to us to indicate that a definite though not complete resistance to reinoculation develops during a long-standing infection.

Charlouis also inoculated ten individuals who had recovered from yaws. In seven the result was positive, the disease running virtually the same course as in normal individuals who were experimentally infected. It is obviously impossible to state whether these individuals were actually cured of their infection or were merely in a latent stage, and the number of years that had elapsed since the onset of the disease is not known.

Treated cases.—The small group of yaws patients that were reinoculated after treatment with neosalvarsan permits some interesting observations. Only one of four cases developed a typical, actively growing granuloma, and this patient had been infected for only three months, the mother yaw being present as well as secondary lesions at the time treatment with neosalvarsan was started. Obviously this period of infection was inadequate to establish any protection against the somewhat severe test of experimental inoculation. One of the other patients had been infected eight months, the mother yaw also being present at the time the injections of neosalvarsan were

started. On reinoculation, slow-growing granulomata developed at each of the two incisions, and after three weeks spontaneous regression set in. The larger of the two lesions was excised and, subsequently, numerous small granulomata appeared at the site of excision, excited perhaps by the surgical trauma. The lesion which was left undisturbed disappeared completely. In the other two patients the infection had persisted for more than a year, and the mother yaws had disappeared completely when the injections of neosalvarsan were given. Both of these patients developed abortive lesions which disappeared promptly.

Of the many possible interpretations of these results it seems plausible to us that these abortive reactions are due to an active immunity and are analogous in a general way to the immediate temporary reaction following the vaccination of individuals immune to smallpox. Indeed, it is the only example with which we are familiar of an abortive reaction developing with a virus for which the etiologic microörganism has been established. It is often difficult to distinguish between active immunity and latent infection resulting in a refractory state. The latter assumption is not plausible in these cases of yaws. The striking effect of neosalvarsan upon *Treponema pertenue*, the prompt disappearance of the clinical manifestations, and the gradual weakening or disappearance of the Wassermann reaction are strong arguments indicating the radical cure of the disease.

Our results throw some light upon the spontaneous course of yaws. After the development of the mother yaw, successive crops of secondary granulomata develop, for the most part by metastatic infection. The Wassermann reaction becomes positive and, also, a measurable degree of immunity slowly develops. This immunity is not sufficient to produce regression of the granulomata already formed, but it seems to be effective eventually in preventing metastatic infection, thereby gradually bringing about the termination of the secondary stage and, frequently, of the disease itself. In other cases, latent foci of infection persist in the bones and in the thickened epidermis of the feet and hands, lasting for many years or throughout life.

The question of recidives in yaws has often been loosely discussed from a clinical standpoint. It involves two aspects; namely, (*a*) whether a patient in the late or tertiary stage of yaws may suffer a recrudescence of the typical secondary or granulomatous stage, and (*b*) whether a patient actually cured of the disease and free of treponemata may experience a typical

reinfection. Our experiments on the reinoculation of clavos cases suggest that latent cases are not likely to develop typical granulomata. The immunity in yaws is not high in degree, and one attack of the disease does not necessarily afford protection against reinfection.

Cross immunity in yaws and syphilis.—In the lower animals, with the exception of the higher apes, the available evidence indicates that experimental yaws terminates spontaneously with the primary stage. A large amount of work has been conducted with the object of determining the relationship between yaws and syphilis. Experiments have been made upon animals and even upon man. With one exception, neither cross protection nor modification of the course of either disease has been observed. A man who had developed yaws was inoculated by Charlouis with syphilis. A typical chancre and characteristic secondary eruption developed. A second patient infected with yaws contracted syphilis naturally, the disease running a typical course in the primary and secondary stages before treatment was commenced. Bahr,(2) on the other hand, noted that in Ceylon syphilis and yaws do not coexist in the same community, and that in Fiji yaws prevails very widely while syphilis is unknown, although there is frequent opportunity for its introduction. He considers that in man a reciprocal protection is developed between the two diseases.

Neisser, Baerman, and Halberstädter,(7) working in Java, found that monkeys successfully inoculated with syphilis were also susceptible to yaws, and vice versa. These findings were confirmed independently by Castellani.(3) Somewhat different results were obtained by Levaditi and Nattan-Larrier.(6) Monkeys infected with syphilis were protected completely against yaws. The results of these experiments might well vary slightly according to the stage of the disease at which the cross-inoculations were performed. Before concluding that yaws affords no protection whatever against syphilis, it would be desirable to demonstrate that some degree of immunity had been established to yaws itself before testing the resistance to syphilis.

Notwithstanding the discrepancies in the clinical and experimental evidence, the accepted opinion to-day leans decidedly to the conclusion that the two species, *Treponema pertenue* and *T. pallidum*, which have so many characteristics in common, do not afford any substantial cross-protection. It is reasonable to assume that, in the process of evolution, these two species arose from a common ancestor. There is no ground, however, for any

profitable speculation concerning the circumstances which led to their differentiation. It is clear from the preceding discussion that the exact extent of this differentiation has not been clearly determined in its biological aspects.

SUMMARY

1. A patient, in the well-developed secondary stage of yaws, was successfully reinoculated with yaws; the lesion soon regressed spontaneously.

2. Two patients in the stage of clavos were reinoculated with yaws. The lesions that developed disappeared very rapidly.

3. The reinoculation of untreated patients suggests that a long-standing infection with yaws produces a definite though not complete resistance to reinfection.

4. Four patients in the secondary stage of yaws were treated with neosalvarsan and reinoculated with yaws several months later. In one a typical granuloma was produced; in the other three atypical reactions resulted.

5. The results of reinoculation of patients cured with neosalvarsan indicate the development of a measurable degree of active immunity in yaws.

6. No evidence was obtained to suggest that the serum of yaws cases under treatment with neosalvarsan has any curative action when injected in yaws patients.

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ILLUSTRATIONS

Plate 1

FIG. 1. Untreated patient, reinoculated with yaws, experimental lesion over the deltoid. Some spontaneous granulomata on the neck.

2. Treated patient, reinoculated with yaws, first case; lesion at the end of the third week.

3. Treated patient, reinoculated with yaws, second case; lesion at the end of the third week.

Plate 2

FIG. 1. Treated patient, reinoculated with yaws, third case; lesion at the end of the third week.

2. Treated patient, reinoculated with yaws, fourth case; lesion at the end of the third week.

3. Fourth case, showing condition of lesion eleven weeks after inoculation.

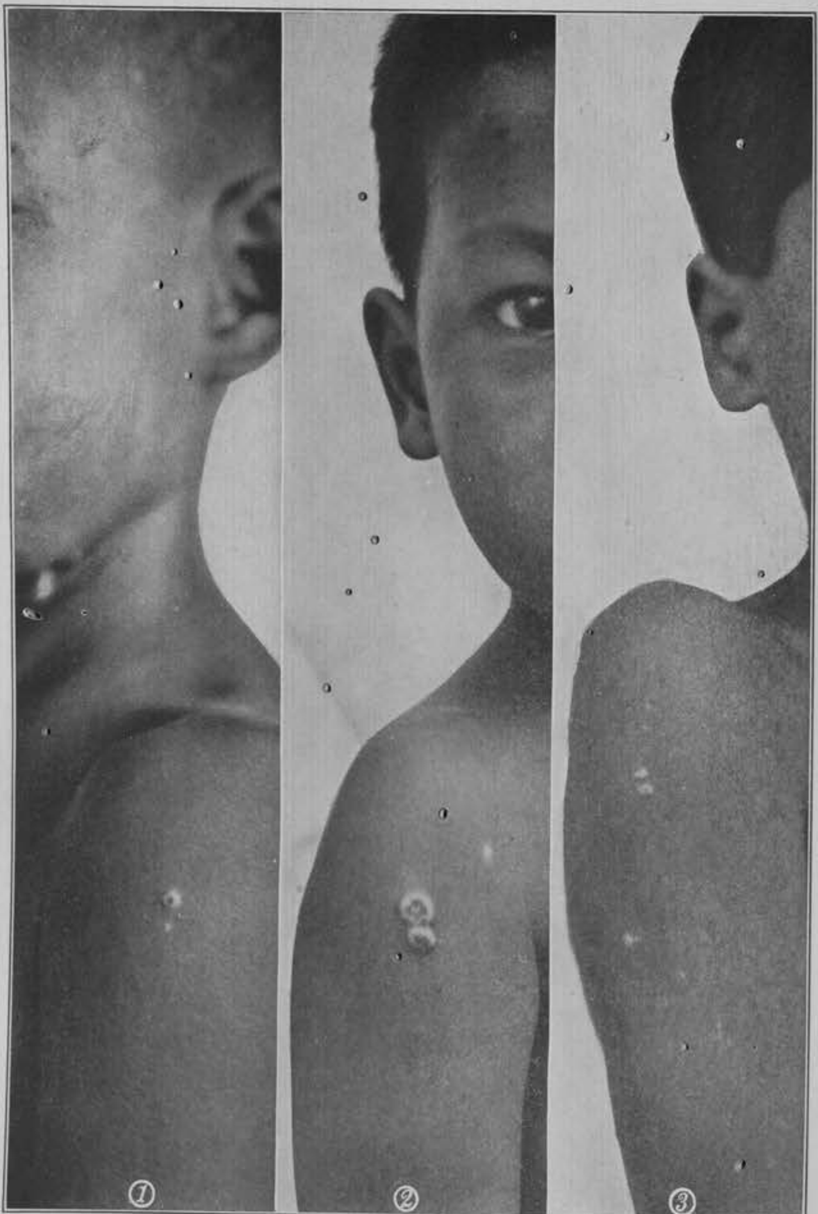

PLATE 1.

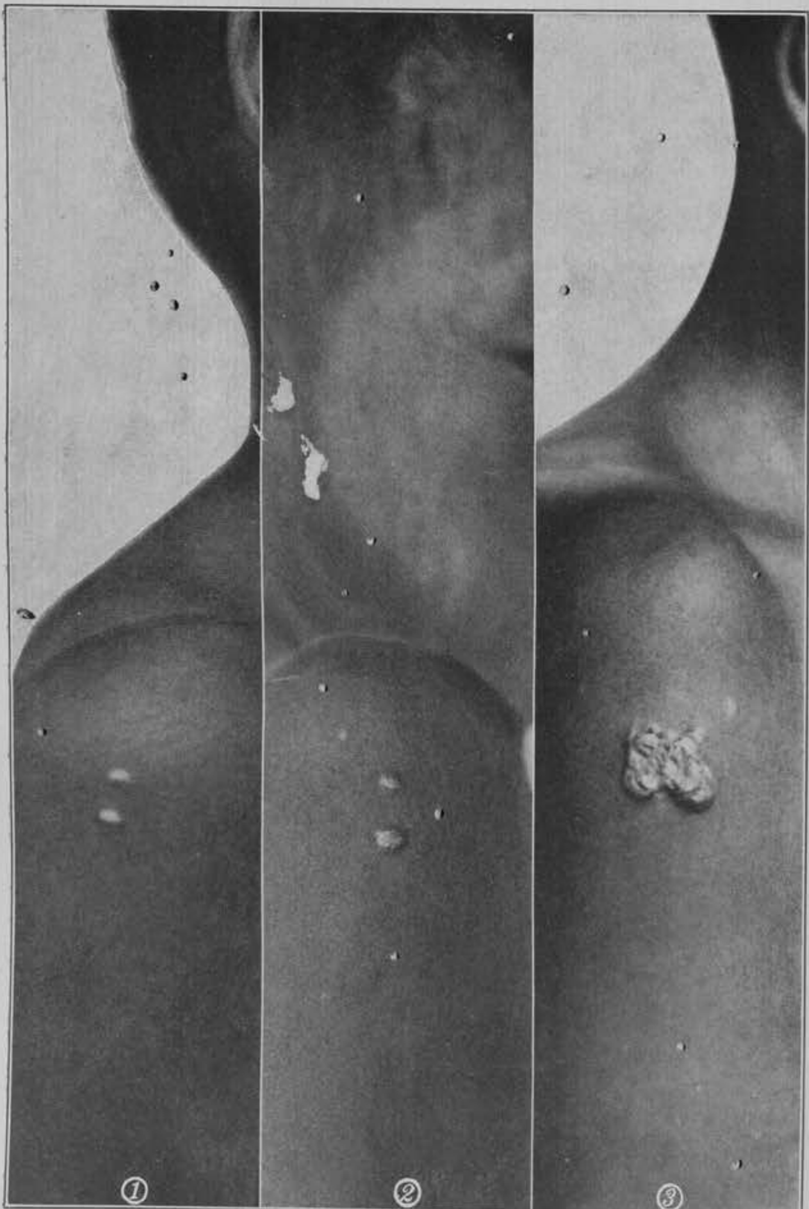

PLATE 2.

PUBLIC-HEALTH ASPECTS OF YAWS

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DISTRIBUTION

Yaws is one of the comparatively few diseases that are limited rather sharply to the Tropics. It encircles the globe in the Torrid Zone, but curiously enough it does not spread when introduced into temperate climates. There are a few records of an occasional isolated case contracted outside of the Tropics, but the disease does not gain a foothold there. Maxwell(8) states that yaws is imported into China from the Straits Settlements from time to time, but soon dies out. These statements apply to the distribution of yaws as it occurs today; it is believed by some authors that certain of the diseases formerly endemic in Ireland may have been yaws.

In several instances the geographical restriction of infectious diseases is readily explained by the corresponding limitation of an essential insect vector. The interest which such sharp limitation arouses is well illustrated by the striking though incompletely studied example of verruga peruviana and oroya fever. These diseases occur in the Andes Mountains and are endemic at altitudes of approximately 1,500 to 7,000 feet (500 to 2,300 meters). Patients when removed to higher or lower altitudes do not serve as foci of infection. Moreover, susceptible individuals may remain in the infected zones during the daytime with impunity, but before nightfall they must proceed to a higher or lower altitude. Hence the inference is drawn that these diseases are transmitted by a night-flying insect limited to this region.

Even within the Tropics it is commonly stated that yaws is restricted to the lower altitudes. Bahr(2) noted in Ceylon that people living at altitudes higher than 800 feet (260 meters) rarely contract the disease, even though the surrounding lowlands are thoroughly infected. A striking exception has been reported by Ricono(10) who describes eight cases in

the Mount Fletcher District in South Africa; Mount Fletcher is 5,500 feet (1,800 meters) high.

In Manila, for many years, physicians have frequently spoken of the occurrence of yaws in the Mountain Province of northern Luzon at elevations varying from 2,500 to more than 5,000 feet (800 to 1,700 meters). I recently passed through this province on a brief visit. In exceptional instances, I found that yaws occurring in the people there might readily have been contracted during visits to the adjacent lowlands where the infection is prevalent. This explanation, however, does not apply in the majority of cases. Doctor Pick, of the Philippine Health Service, estimates that he has treated 2,800 cases of yaws in the Mountain Province. He describes the lesions as limited largely to the mouth, the anus, and the vulva, with but few granulomata occurring on other portions of the body.

The limitation of yaws to the Tropics inevitably suggests that it may possibly be transmitted by bloodsucking insects in analogy with other spirochætal diseases such as relapsing fever. This idea has been emphasized by Bahr. In its support it should be mentioned that the mother yaw frequently develops on the lower extremities, which recalls that, in bubonic plague, the causative organism is commonly introduced in the lower extremities, the initial buboes appearing in the groin.

Although the circumstantial evidence, suggesting an intermediate insect host, should not be forgotten, it seems advisable to adhere to the prevailing view that yaws is ordinarily disseminated by contact. The only feasible procedure for attempting the control of yaws in a given community consists in eradicating the foci of infection by treatment of the individual patient.

No plausible suggestion has been advanced concerning the probable explanation of the usual restriction of yaws to the warmer regions of the Tropics. In seeking for a solution, it is perhaps well to keep in mind the possible effect of surface temperature upon the development of the granulomata. Considering first the typical case of the lowlands, it is noteworthy that, of the multiple miliary lesions distributed metastatically from the mother yaw, only a small proportion progress to fully developed granulomata. Although these granulomata may develop on any part of the body, they show a striking predilection for the muco-cutaneous orifices, for the axillæ, and also for the groin and the popliteal spaces. These locations

are either moist or they are protected, to some extent, by the body clothing. However, in the Mountain Province of the Philippine Islands it would seem that the majority of the patients escape the usual general distribution of yaws over the body. These people are very primitive. The men wear only a breechcloth, and the clothing of the women is inadequate to maintain the ordinary surface temperature of the body. The possibility naturally suggests itself that, in the dry skin exposed to the low temperature, the granulomata of yaws might develop only with difficulty.

INCIDENCE

In drawing up any detailed plans for the treatment of yaws in an endemic area, one is often embarrassed by the impracticability of securing even an approximate estimate of the total number of cases. On making inquiries, one is frequently told that almost everybody has fresh active yaws. To assume that such is the case would be a fallacy. There is considerable clinical and also some experimental evidence that the majority of patients do not pass through more than one period of typical florid granulomatous eruption. Let us allow the fairly liberal period of two years for the granulomatous stage and assume an average duration of life of fifty years for the community. Considering the disease to be endemic rather than epidemic, the maximum number of cases in the granulomatous stage would average 40 per 1,000 of the population. Obviously such a calculation is merely of theoretical interest. In Parañaque, yaws has been endemic for many generations; recently the Philippine Health Service treated nearly all of the active cases. There were 275 cases in a population of 8,541, or 33 per 1,000 of the population. Unfortunately, in many isolated districts of the Tropics even an approximate census of the population is not available.

The disease is restricted almost entirely to the native people and especially to those of the poorer classes who are inclined to give scant attention to simple personal hygiene. In many localities, yaws might well be classed as one of the diseases of childhood. At the Parañaque clinic 69 per cent of the cases occurred in children under 11 years of age, and the total of those under 16 years was 88 per cent. At Yamasá in the Dominican Republic the parents freely make a practice of exposing children to the disease because they feel that the sequelæ,

especially clavos, are likely to be less severe when the disease develops during infancy.

DIAGNOSIS

For public-health purposes, the diagnosis of the typical granulomatous stage is a simple matter. Secondary pyogenic infection may mask or confuse the diagnosis. Some of the atypical infections may require a little care in differentiating them from cutaneous leishmaniasis, from granuloma inguinale, and from syphilis. Indeed, in obscure cases, it may be impossible, even with the most-refined means of investigation, to differentiate absolutely some of the tertiary lesions of yaws from tertiary syphilis. The X-ray is of assistance in differentiating the bone lesions of the two diseases. Real difficulty arises in the case of ulcers. The history may be wholly unreliable; and the clinical manifestations, the laboratory findings, and the response to treatment are inadequate for differentiating syphilitic and frambœsial ulcerations.

For the purpose of simply checking the spread of yaws in a community it is perhaps sufficient to treat only the primary and secondary stages. We have found no reliable indications in the histories of patients that a mother yaw has been contracted from a tertiary case. On *a priori* grounds it seems improbable that a tertiary ulcer would afford a serious focus of infection for the spread of the disease.

On humanitarian grounds, and for the sake of relieving the extensive incapacitation caused by the late lesions of yaws, it is imperative to extend the treatment to latent cases. In some regions, the condition known as clavos is especially important. Multiple granulomata develop in the thickened epidermis of the soles of the feet. An attempt at healing takes place and a hard core of tissue forms in the center which eventually falls out leaving deep "nail" holes. Hence, in Spanish-speaking countries, this condition is often called "clavos." Excoriation and fissuring of the epidermis continues, and the pain persists. The results of the serological tests and the therapeutic response indicate strongly that active infection with the causative treponema is responsible for the continuance of these lesions.

Finally, a word must be said in regard to the control of field work by the Wassermann reaction. The decision regarding the advisability of including a Wassermann outfit in the

field equipment is probably an individual question and might well be allowed to vary according to local conditions. It is certainly superfluous for the diagnosis and treatment of the ordinary granulomatous stage, being indeed without value as a guide in the immediate effect of treatment. The Wassermann reaction is of distinct value in eliminating some of the nonspecific ulcers which would not be benefited by salvarsan. As a means of diagnosis the more practical procedure could be substituted of the therapeutic test of injecting salvarsan. Unfortunately this procedure is slow, and the results are often masked by the extensive secondary infection. The employment of the Wassermann reaction requires at most only one additional member in the personnel and adds immeasurably to the satisfaction of the work.

TREATMENT

No difficulty whatever exists in deciding upon the remedy which is most suitable for field use. Neosalvarsan at present stands alone in its efficacy, its relative ease of administration, and its availability. Nevertheless, it is a powerful agent and must be employed judiciously by medical men, or under their immediate personal supervision. From the viewpoint of modern hospital practice, intravenous injection is often regarded as the ideal attainment in therapy. Indeed, to many it would seem to be a step backward to suggest oral administration in place of intravenous injection. However, a drug which is efficacious only when injected into the tissues of the body suffers a very real limitation in its general use even in a modern community. For example, the control that exists over malaria to-day in the better-regulated communities would be greatly hampered if quinine could be administered only by injection by trained individuals.

The various salvarsan preparations fall short of the ideal in this requirement for they are not sufficiently efficacious when administered by mouth for the practical treatment of yaws. Brochard(4) reported fairly successful results in the treatment of nine cases of yaws with old salvarsan administered by mouth. Recently Doctor Albert, in association with Doctor Rosal at the Philippine General Hospital, has tested the oral administration of salvarsan in the treatment of yaws. Neosalvarsan given in dilute solution in daily doses of 60 milligrams was borne without serious nausea by children of 12 years of age. After a week of treatment no noticeable improvement had occurred.

Old salvarsan was then given in gelatine capsules by mouth in daily doses of 150 milligrams. Improvement was noticeable within a week and was very well marked after two and a half weeks. These cases have not yet been reported in full. It is evident, however, that the oral administration does not produce sufficiently rapid improvement to permit its employment in field work. The same objection applies to Castellani's treatment with tartar emetic. With the impatience typical of the average patient, the treatment would not be voluntarily continued until a cure was effected. Indeed, it has not yet been demonstrated serologically that the administration by mouth of either salvarsan or tartar emetic will effect the absolute cure of yaws.

However, there is some ground for encouragement in the fact that salvarsan given by mouth does produce very definite improvement in yaws. It hardly seems to be an unreasonable chemical requirement that effective derivatives should eventually be produced suitable for oral administration in the radical cure of yaws. Indeed, this might afford a preliminary step toward the enlargement of the field for treating and controlling the related disease, syphilis.

A very real question comes up in deciding whether neosalvarsan should, under field conditions, be injected intravenously or intramuscularly. The former is the method of choice, but the number of men available for the Tropics who are adequately trained in the very simple technic of intravenous therapy is surprisingly limited. Moreover, successful injection in a difficult vein, with only untrained assistants to hold the child, perhaps in the uncertain light of the rainy season, requires a greater degree of skill than is necessary in a modern hospital. The procedure is relatively laborious and time-consuming. On account of the contamination with blood, a fresh syringe must be used for each injection. According to the United States Public Health requirements, a minimum of five minutes must be employed for each intravenous injection. Therefore, exclusive of all the time for the preparation of materials, one individual under these restrictions can hardly inject more than ten patients per hour. On the other hand, for intramuscular injection a single syringe, by merely changing the needle, can be used repeatedly without resterilization, and one individual can, without special effort, inject two or three times as many cases as in intravenous work. I have had considerable expe-

rience in Santo Domingo with both methods. After six weeks of intravenous work at Monte Plata, intramuscular injection was adopted at San Cristobal where two hundred cases of yaws in the granulomatous stage were treated. At the outset, it was hoped that the slow absorption from the intramuscular injection would largely obviate the reactions. The results were disappointing in this respect; the reactions were very common, and some of the chills were severe. The therapeutic results however were excellent; the lesions healed promptly, and very few patients required more than two injections. These results are not surprising in view of the accepted teaching regarding the pharmacological action of the salvarsans. According to the consensus of opinion, salvarsan per se is not efficacious against the treponema, but it is readily oxidized in the tissues to a more active product. In the gastrointestinal tract there is no tendency toward oxidation, but in the blood stream oxidation takes place easily, and in the muscles it occurs still more rapidly.

The most serious drawback to the intramuscular procedure consists in the very extensive and at times painful induration at the site of injection. Absorption takes place very slowly. In some communities this method of treatment would seriously injure the confidence of the people, and it would be essential to employ intravenous injection.

To many it may seem very radical to recommend such a toxic agent as neosalvarsan for mass treatment in field operations. However, it was successfully employed in Santo Domingo for more than 1,200 patients. This was accomplished without any trained workers for assisting during the injection or in the immediate after-care of the patients. It was necessary to violate, in minor respects, many of the conditions laid down by the United States Public Health Service for the administration of neosalvarsan. In the first place an excellent grade of distilled water was prepared almost daily in the camp for making up the solutions. However, a sufficient supply of distilled water was not available for boiling syringes; rain water especially collected from a clean canvas tent was employed, although the water remaining in the syringes necessarily contaminated the solution of salvarsan slightly. In the intravenous injection of children, especially a struggling child, it was by no means possible to adhere to the required time of five minutes for the entire injection. For the sake of economy,

the main stock of neosalvarsan was obtained in 3-gram ampules; and, here again, with the various delays incident to injection, it was often impossible to complete the injection of the entire quantity of solution within thirty minutes after its preparation; occasionally as much as forty-five minutes was required. Also, since no ice was available, the solution was always prepared with water at summer temperature. No control could be exercised over the diet or the preliminary catharsis of the patients. In view of these drawbacks, doses slightly smaller than the standard were employed. The scheme of Bergen(3) was modified as shown in Table 1.

TABLE 1.—*Dosage of neosalvarsan.*

	Bergen.		Modified scheme.	
	Age.	Dose.	Age.	Dose.
	Yrs.	*mg.*	*Yrs.*	*mg.*
Adults		900		600
Subadults	18 to 20	750	18 to 20	500
Do	16 to 17	600	16 to 17	450
Do	10 to 15	450	10 to 15	400
Children	7 to 10	300	7 to 9	300
Do	5 to 7	225	5 to 6	225
Do	3 to 5	150	3 to 4	150
Infants	2 or less	75	2 or less	75

This table is intended, of course, only as a general guide for the various ages or, in many instances, for the apparent or the probable age. Obviously, the dosage must occasionally be reduced, or treatment deferred altogether in patients showing marked emaciation, outspoken pulmonary or cardiac disease, and also in febrile conditions other than those due to yaws. The infrequency of arteriosclerosis and renal insufficiency in the Tropics eliminates any necessity for routine examination of the urine.

Other methods of treatment have been recommended, more especially for avoiding the use of injections under unfavorable conditions. Castellani's formula(5) containing potassium iodide and tartar emetic has met with considerable favor; however, this treatment must be continued daily for approximately one month. An adult, or a child over 14 years, must take 300 grams or more of potassium iodide. The cost of this item alone is rather more than 4 pesos as contrasted with 1.8 grams of neosalvarsan at about 0.80 peso.

When one is cut off for weeks from a base of supplies, the essential equipment for the treatment of yaws with neosalvarsan is not complicated, even in regions where the simplest articles of household life are wholly lacking. The exact details will vary with the preference of the individual. The following unit was found practical, and is suggested as a suitable basis for the selection of an outfit:

1 small water still with tin condensing coil.
2 bottles (0.5 liter) for receiving distilled water.
A supply of, suitable water for washing and boiling syringes.
1 khotal or primos stove with complete set of wrenches and pliers and fine wire for cleaning and soft leather for repacking the piston. (New models have a valve for regulating the size of the flame.)
10 gallons of kerosene, allowing 1 quart for ordinary use of stove continuously for eight hours. Alcohol for priming stove.
1 small box for shielding the stove from drafts. This is essential. The wooden case commonly used for two 5-gallon oil cans is satisfactory.
12 syringes, Luer type, 10 and 20 cubic centimeters capacity (for intravenous work), an ample supply of needles, and a stone for daily sharpening of these. If steel needles are used alcohol and ether saturated with vaseline are convenient for drying them when not in use.
2 pairs of ordinary forceps.
2 wide-mouthed bottles 100 cubic centimeters (with glass stopper or cover) with graduation marks. (A mark at 60 cubic centimeters for dissolving 3-gram ampules of neosalvarsan at the minimum dilution of 0.1 gram per 2 cubic centimeters. Additional graduations can be made with a syringe.)
1 container (of tin) for boiling water for dissolving salvarsan.
1 container for used syringes.
2 copper instrument boilers (25 by 12 by 6 centimeters) with removable tray and with wire tongs for handling tray. Soap, alcohol, and cotton for preparation of patients.
2 soft rubber tourniquets.
2 triangular files.
1 set of cards for records of patients. (Cards are preferable to a bound book for convenience in locating a patient's record on his return visits.)
Ampules of salvarsan. (3 grams each for the main stock with a few small ampules, 0.6 gram each, for convenience in adjusting the quantity of solution required in closing the day's work.)
Schedule of dosages for varying ages.
Stethoscope.
Clinical thermometers and reagents to test for albumin in the urine.

The main cost of the work is the expense of personnel for the administration of neosalvarsan. Fortunately, in some localities in the Philippines, the Government hospitals with their person-

nel are already available. In these it would be entirely feasible to treat yaws continuously. There are other regions, heavily infected, in which traveling dispensaries could be operated intermittently. The expense of neosalvarsan for Government use is remarkably low; namely, 20 cents United States currency (40 centavos Philippine currency) for 0.9-gram quantities. Therefore, for a series of three injections of 0.6 gram each for an adult, the total cost of the drug would be 80 centavos Philippine currency. The majority of the cases, however, occur in children; for an infant the neosalvarsan for a series of three injections costs 10 centavos.

The total expenditure in money that would be required to bring yaws under control in a given community would necessarily vary widely in different countries. Moreover, if the work were to be pressed rapidly, it would be correspondingly much more expensive. The time required must also vary widely. It would depend in the main upon three factors; namely, (*a*) the readiness with which patients present themselves for treatment; (*b*) the consistency with which they return for repeated injections; and (*c*) the total percentage of cases that report for treatment.

In primitive communities we have found that the people would await with interest the result of the injection of the first few patients. Then they would present themselves even more rapidly than desired. There are always, however, a few stragglers. Moreover, with the striking benefit following one or two injections, there are many who do not bother to return for repeated injections. Furthermore, one cannot expect that 100 per cent of the cases will report voluntarily and with reasonable promptness. The operation of a dispensary for a single period of a few weeks for the treatment of all accessible patients in a given area would certainly be altogether inadequate to bring the disease under permanent control. Repeated visits would be required at intervals of perhaps six or twelve months. Six months after closing the dispensary at Parañaque, an inspection showed the presence of 76 cases of yaws. They were classified as follows: Fifty-six cases were reported to have developed since the closing of the dispensary; 8 were old cases that failed to report for treatment; 12 were only partially cured or were relapses. Too much confidence cannot be placed on this small number of relapses, since two-thirds of the cases received only one injection. In several places a good beginning has been made, only to have the preliminary advantage lost through a

gradual or sudden decline in interest resulting in merely spasmodic activity or even in cessation of the work.

PERMANENCY OF RESULTS

The available data indicate that there is but little tendency to recurrence or reinfection after treatment with salvarsan. In the Windward Islands in 1912–1913, only 5 per cent of relapses occurred after treatment with salvarsan (606).(1) Bergen noted 4.9 per cent of relapses, or possibly reinfections, following the intravenous treatment of 1,626 cases of yaws with salvarsan after a period of thirty-four months; 2.6 per cent of relapses occurred in 655 cases treated intramuscularly. Kurien(7) records 11 per cent of relapses in the treatment of about 3,000 cases with various preparations of salvarsan, but apparently 90 per cent of the patients received only one injection. Thorough treatment of a community at once reduces to a minimum the foci of infection. It is probable that, having once had the disease, many patients will profit by their lesson.

Fairly extensive treatment of yaws has been practiced of late years, particularly in some of the hospitals of the West Indies. There are doubtless valuable reports from such hospitals to which I have not had access. Indeed, it would be very important to secure information concerning the incidence of yaws in a community in which intensive treatment with salvarsan had been practiced consistently for several years. In Java, in 1913, the treatment of yaws with salvarsan (606) was given thorough consideration. The decision was referred to Kloppers,(6) who concluded that the plan was not feasible on account of the great expense of salvarsan at that time. McDonald,(9) in 1915, suggested measures leading to the absolute eradication of yaws in Antigua, a small island of about 108 square miles in the Leeward group in the West Indies.

SUMMARY

Neosalvarsan in the hands of medical men can, with proper precautions, be used safely on an extensive scale under field conditions. The diagnosis of the granulomatous stages of yaws is simple. A Wassermann outfit, though not indispensable, is a valuable adjunct even in field work. The treatment presents no special difficulties. In the Tropics, routine examination of the urine is not a prerequisite before administering neosalvarsan.

Certain details of field operations are still sub judice, or are subject to modification according to varying local conditions.

It has not been accurately determined whether latent or tertiary cases of yaws constitute important sources in the infection of susceptible individuals. Further observations are desirable regarding the feasibility of substituting intramuscular for intravenous injection of neosalvarsan, especially when work is conducted under the disadvantage of limited personnel.

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THE HISTOLOGY OF HEALING YAWS

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TWO PLATES

The rapid curative effect of neosalvarsan upon the cutaneous lesions of yaws is probably the most spectacular achievement of modern chemotherapy. Disfiguring and loathsome sores, oozing pus and blood for months, will begin to dry and encrust a day or two after an intravenous injection of this drug, and in an incredibly short time will fade away almost magically. Since Strong,(12) in 1910, first demonstrated his successful results in the treatment of yaws with salvarsan, many observers have commented upon the immediate improvement in gross appearance of lesions following this treatment, but it has been impossible to find any description of the more minute changes that take place in the tissues of the nodules. The rapid encrustation and dropping off, so to speak, of a lesion which is known to be largely an epithelial hyperplasia, is difficult to explain from gross appearances alone. It was consequently of interest to determine what happens to the causative organisms, and how such a sudden subsidence of the inflammatory process is brought about.

Through coöperation with the Philippine Health Service at Parañaque and the Philippine General Hospital it was possible to excise suitable lesions before and at varying lengths of time after treatment, and a description of the histopathology of these specimens is the basis of the present paper.

There are several excellent descriptions of the typical cutaneous lesion of yaws. Many of them, and some the best, were made before *Treponema pertenue* had been demonstrated by Castellani(1) to be the etiological agent, and they are therefore incomplete. Others were based upon study of a single example, consequently presenting only one stage; but, taken altogether, this phase of the pathology of the yaw has been carefully studied and our understanding of the inflammatory process is fairly

complete. One still undetermined point is how the secondary lesions begin and where they begin—whether in the corium or in the epidermis.

Practically all the histological studies of human material have evidently been made with lesions from the eruptive stage of the disease following primary local infection. There can be no reasonable doubt that this exanthem is due to the localization in the skin (2) of treponemata from the circulating blood entering through the mother yaw. Whether they pass through capillaries and papillæ into the epidermis without obvious effect and there proliferate, injuring surrounding tissue, or whether their initial growth with primary inflammatory reaction is in the perivascular tissue of the papillæ with secondary invasion of the epidermis is uncertain.

Charlouis, (3) describing in 1881 the histology of a pinhead-sized papule, thought the primary changes occurred in the corium. He described a dilatation and tortuosity of the superficial plexuses and then of the deeper vascular plexuses accompanied by a diapedesis of leucocytes, an elongation of the papillæ, and an infiltration of granular cells between the fibers of the corium. Pontoppidan (7) in 1882 placed the primary seat of the affection in the prickle-cell layer of the epidermis. Macleod (4) in 1901 carefully described several stages of the eruption and concluded that in the earliest skin manifestation which, following Nicholle, he called the "squame," the initial stage occurred in the superficial layers of the corium as was evidenced by a slight dilatation and tortuosity of the papillary and subpapillary vessels in the neighborhood with a marked extravasation around them of leucocytes which passed therefrom into the lymphatic spaces between the fibrous bundles and eventually reached the epidermis. In 1907 Schüffner (9) demonstrated *Treponema pertenue* for the first time in sections, by the silver method, and found the organisims only in the epidermis. Later investigations (6, 10, 8) have confirmed this observation on the limited distribution of the organisms, and Siebert (11) is of the opinion that they proliferate only there, because of the activity of cocci from the surface which stimulate a local leucocytic exudate favorable for their growth. In some of my preparations, as will be described later, treponemata were demonstrated in great numbers in the perivascular tissue about the terminations of papillæ; for this and other reasons it seems probable that the secondary yaw begins with a lesion in the papillæ and spreads

from there to the epidermis where conditions of growth are subsequently more favorable.

However, following the first and yet undetermined lesion, there are continued injury and reaction which result in a fully developed papillary nodule. The architecture of the nodule is well known, the essential feature of it being a small papule, or papillary, frambœsiform granuloma, irregularly round or oval, discrete or confluent, elevated a few millimeters to a centimeter or more above the surrounding skin, and covered in its earlier stages by a soft yellow scab, beneath which is a granular seropurulent, sometimes hæmorrhagic surface formed of elongated papillæ, almost reaching the exterior and bleading easily, with thickened epidermis between. Later the surface is drier and coated with keratinized epithelium. Microscopically the epidermis is greatly thickened, swollen with fluid, infiltrated with leucocytes distributed diffusely and as miliary abscesses. The epithelium is prematurely desquamated and shows various degenerative changes, later developing a hyperkeratosis. The elongated papillæ are œdematous, hæmorrhagic, and infiltrated with cells of various types, and deeper in the corium are dense aggregations of mononuclear cells; in the earlier stages those of the large lymphocytic type predominate, but later the aggregations are composed almost entirely of plasma cells, a stage which Unna(13) described. Several observers note the absence of vascular thickenings and of definite perivascular cellular infiltration in the corium, in contrast to cutaneous lesions of syphilis.

In the following descriptions the histological structure of stages observed will be considered in detail with the changes noted in them following treatment by intravenous injection of neosalvarsan.

MATERIAL AND METHOD

Typical early secondary yaws of from one to four months' duration were removed from four individuals before they had received treatment. From one of these persons (case 1) a second yaw, as nearly at the same stage of development as possible, was excised forty hours after intravenous injection of neosalvarsan. From another (case 2) a second yaw was excised three days after treatment and a third seven days. Only lesions removed before treatment were studied from the remaining two cases of early yaws (cases 3 and 4).

From a fifth case a dry, apparently regressing or stationary lesion of four or five months' duration was removed before treatment, and another similar nodule three days after an injection of neosalvarsan.

Sections of nodules from each case, measuring 1 millimeter in thickness, were immediately placed in Zenker's fluid and in 10 per cent formalin. The Zenker-fixed material was embedded in paraffine and stained with hæmatoxylin and eosin. The formalin-fixed tissue was stained by Levaditi's silver method.(5)

CASE 1

Primary yaw appeared on the ankle four months previously, followed in one month by a crop of secondary papules over the entire body, accompanied by occasional attacks of fever, chills, and pain in the bones. Many of the lesions increased in size until at present they measure from 0.5 to 1 centimeter in diameter. They are discrete, elevated, rounded or oval nodules, the surface fungating and covered by an opaque, yellow, moist crust.

Yaw 1.—October 8. Such a yaw on the chest, measuring 0.8 centimeter in diameter, was excised by Doctor Franco under local anæsthesia. On cut section it showed a firm, grayish yellow, thickened epidermis containing a few minute hæmorrhages, evidently in an acute stage of inflammation. Pieces of tissue were fixed immediately in 10 per cent formalin and in Zenker's fluid.

Microscopically there is an acute inflammation of the skin, with an enormous exudate of leucocytes in the thickened epidermis and a serous, in places hæmorrhagic, exudate in the elongated papillæ of the corium. The acute inflammatory changes in the corium are confined almost entirely to the lengthened and swollen papillæ and to a thin zone just beneath the basal layer of epithelium elsewhere. The reaction is characterized especially by an exudation of serum which spreads apart collagen fibrils and fills up the spaces between them. To a less extent leucocytes and red cells are present in this perivascular tissue; in places fibrin is deposited and small hæmorrhages have occurred.

Corresponding to the elongation of papillæ the total width of the epidermis is about fifteen times the normal, and most of this increase in volume is due to the accumulation of leucocytic and serous exudate within this layer. Foci of leucocytes occur in the form of miliary abscesses which are numerous and situated most characteristically in a midzone somewhat nearer the

corium. The upper portion of hair follicles does not escape invasion. Leucocytes are also scattered in greater or lesser numbers throughout the epidermis in intercellular spaces. These spaces are dilated by the presence of serous exudate. A thin layer of purulent exudate, often communicating with miliary abscesses below, overlies the surface. There is no ulceration through the epidermis, though the abscesses sometimes break through the basal layer. There are various degenerative changes in epithelial cells; some are pale and shrunken, others vacuolated especially about the nucleus, and many are cast off into abscess cavities where they undergo hyaline necrosis. Normal differentiation is arrested, keratinization does not occur, and nuclei are preserved more or less intact out to the surface. There is an absence of general pigmentation in the inflamed area, though in Levaditi preparations large, branching, pigment strands can be found here and there in the stratum germinativum. Mitotic figures in epithelial cells are abundant.

In the œdematous perivascular connective tissue, which is relatively poor in cells, there are, in addition to the polymorphonuclear, a considerable number of the large mononuclear type, which however are rarely engaged in phagocytosis; this is in striking contrast to the condition in yaw 2, following treatment. The large mononuclear cells are fairly numerous also in miliary abscesses. There are a few lymphocytes and there is a moderate increase in fibroblasts, some of which are to be found in mitosis, but no plasma cells appear.

In the superficial layer of the corium there is a mononuclear infiltration, but this is not nearly so abundant as in case 2. Most of the cells are of the lymphocytic type, though small groups of plasma cells are to be found, and there are many polymorphonuclears. The arrangement is perivascular. The mononuclear-cell exudate does not extend so deeply into the corium as in case 2 but, even so, there are a few plasma cells accumulated about coils of sweat glands. Eosinophiles are not numerous in the lesion, but there are a few irregularly scattered both in the corium and in the epidermis.

Levaditi preparation.—Sections stained by Levaditi's silver method disclose an enormous number of treponemata, especially in the epidermis. They are present in great abundance in the miliary abscesses and in areas of epidermis densely infiltrated with leucocytes. A few can be found in the epithelium at the margins of abscesses where there is no cellular infiltration. Here the treponemata lie in the dilated intercellular spaces, and even

within the cells themselves, especially those showing necrosis or advanced degeneration. No definite evidence of phagocytosis of the organisms by leucocytes has been observed, but in those miliary abscesses which appear oldest, as indicated by leucocytic disintegration and more superficial situation, the organisms are much less abundant than in the newly forming ones which lie deeper in the epidermis. From this it is inferred that the treponemata disintegrate and disappear gradually in the presence of abundant polymorphonuclear leucocytes.

While the epidermis is undoubtedly the most favorable site for the growth of these organisms they are not in this lesion entirely confined to the epithelial layer, but occur in great numbers in œdematous perivascular connective tissue in certain of the long papillæ which extend far up into the thickened epidermis. They are present only in the terminal portions, and in only a few papillæ.

Yaw 2.—October 10. Forty hours after the injection of 0.3 gram of neosalvarsan intravenously the lesions are pinkish instead of yellow and purulent, less elevated, and much improved. Yaw 2, measuring 0.7 centimeter in diameter, was removed by Doctor Franco.

Even in so short a period there is marked change in the histological picture, especially of the epidermis. On the surface is a thin layer of leucocytes and desquamated epithelial cells sometimes communicate with the remnant of a miliary abscess deeper down; but miliary abscesses and foci of dense cellular infiltration are rare within the epithelial layer. There are still great numbers of leucocytes irregularly scattered throughout the epithelial layer, lying in intercellular spaces and sometimes aggregated in small nests, but the great mass of them have been cast off onto the surface or removed in other ways. The thickened and elongated epithelial columns are much more compact than in the previous section, due largely to the loss of intercellular exudate.

The papillæ extending upward into the thickened epidermal layer are still greatly swollen by serous, fibrinous, and cellular exudate and by dilated blood vessels and capillaries. Polymorphonuclear cells appear to be more numerous in the perivascular exudate than before treatment, but their conditions are essentially altered. Many are being engulfed in great numbers by the phagocytic activity of large mononuclear leucocytes, which appear now to be the most active component of the lesions; others are necrotic.

Large mononuclear phagocytes are present in great numbers and are not confined to the papillæ but are to be seen in considerable abundance in interepithelial spaces; engulfing leucocytes wherever they find them. The cytoplasm of many is filled with the digesting remains of these cells, and they are present in no less abundance in the corium where they are also engaged in phagocytic activity, picking out only polymorphonuclear cells which lie among plasma cells and lymphocytes in a number exceeding that of the previous lesion. These active cells are removing leucocytes rapidly from the lesion, not only by local digestion but by transportation, as is indicated by their presence in dilated lymphatics; otherwise, there is no observable change in the cellular exudate. Eosinophiles are present, as in the previous lesion, but they are not being phagocytized. Small accumulations of fibrin at the tips of certain papillæ are invaded by mononuclear cells which have assumed the shape and appearance of epithelioid cells. Some of the vessels of the papillæ contain fibrin thrombi thus invaded.

Levaditi preparation.—These sections show no treponemata. It thus appears that following injection of neosalvarsan treponemata are rapidly destroyed and disappear from the lesion. With the removal of this active pathogenic agent reparative processes immediately ensue.

CASE 2

Four months previously the mother yaw developed on a finger. One month later secondary lesions appeared over the entire body, accompanied by swelling and pain over bones and joints. Lesions on arms, legs, and feet were only macules and dried up; those on the face, neck, chest, and hands have grown to be typical yaws measuring 0.5 to 2 centimeters in diameter, elevated and, when first seen, moist and semitranslucent, having a yellowish, honeylike surface. Ten days later, at the time of removal of the first lesion, they are still soft but more opaque, yellow, and mottled, with small hæmorrhages.

Yaw 1.—September 1. A yaw measuring 1.5 centimeters in diameter having the above-described yellow, purulent, and hæmorrhagic appearance was excised by Doctor Franco from the left side of the back after the injection of novocaine about its margins. The yaw was totally removed with a portion of corium beneath. Sections 1 millimeter thick were immediately fixed in 10 per cent formalin and in Zenker's fluid.

Section through the freshly excised nodule shows a smooth, fairly firm, moist, semitranslucent, grayish and yellowish cut surface of greatly thickened epidermis contrasting with the softer, more-pliable corium beneath. There is no crust, only a thin layer of seropurulent exudate on the rather coarsely granular surface. Near the surface are minute reddish purple points, evidently hæmorrhages in the epithelium. The gross appearance shows that the yaw is essentially a thickening of the epidermis, in which there is an acute inflammatory exudate but no distinct ulceration. The thickened epidermis measures 3 millimeters in width.

Microscopical examination.—The pieces of tissue fixed in Zenker's fluid were embedded in paraffine in the usual way and thin sections stained with hæmatoxylin and eosin, carbol-anilin-fuchsin for bacteria, and by other special methods.

Microscopically there appears a violent acute inflammation of the epidermis and the immediately underlying corium. One is at once impressed by the greatly elongated papillæ of the corium and the deep penetration of corresponding intervening epithelial pegs. The total width of the epidermis is more than twenty times normal. The most acute exudate is within the epidermis and at the apices of papillæ. Over the apices of many of those papillæ, which extend outward often almost to the surface, and in the surrounding epidermis, there is extensive hæmorrhage, the red cells often lying enmeshed in a coarse network of fibrin. Here and there are small pockets of the granular coagulum of serum; but the most abundant and characteristic component of the exudate is the polymorphonuclear neutrophilic leucocyte. Such leucocytes are present everywhere in enormous numbers throughout the swollen, distorted, and hyperplastic epidermis. They are most numerous in a zone just above the basal layer of epithelium, and least numerous in the deep, thick, epithelial pegs and hair follicles. They occur in the form of discrete or confluent miliary abscesses, rupturing, pushing aside, and dissolving masses of epithelium. They lie in great numbers diffusely scattered throughout wide areas within intercellular spaces between shrunken epithelial cells which are pushed apart by quantities of intercellular fluid, and they wander less conspicuously, but still in great numbers, between the cells of the less-injured epithelial pegs and hair follicles. They sometimes accumulate in dense groups at the tips of papillæ beneath the epithelium, and not infrequently a miliary abscess within the

epithelium ruptures through the basal layers and becomes bounded below the connective tissue of corium. The elongated and widened papillæ and a thin layer of corium just beneath the basal epithelial cells constitute the least cellular portion of the lesion. Here a loose reticulum of collagen fibrils, the wide interstices of which are filled with serous exudate, support enormously dilated blood vessels and gaping lymphatics. There is an active diapedesis of polymorphonuclears going on, and they are the most numerous cells. There are in addition a few plasma cells, fewer lymphocytes, and a number of fibroblasts evidently greater than could be normally present. Many of the smaller blood vessels and lymphatics must also have been produced in the general inflammatory activity.

Beneath this zone of œdema the denser corium is filled with compact masses of mononuclear cells which fade off into the depths of the corium in the form of small isolated cellular islands. Where infiltration is densest the collagenous connective tissue has been pushed apart and its fibrils separated until only a thin wavy reticulum remains. While blood vessels of various sizes course through these areas, the distribution of cells is so extensive that there can hardly be said to be a perivascular arrangement, although deeper in the corium there is distinct perivascular infiltration. The majority are plasma cells with numerous lymphocytes which not infrequently form the nucleus of a group with the periphery bounded by a thick zone of plasma cells. There is also a generous sprinkling of polymorphonuclears, especially on the more superficial side. In the depths of the corium there is a cellular infiltration not only about blood-vessels but also about coils of sweat glands and, to a less extent, about hair follicles. These infiltrations are plasma cells and lymphocytes. There are a few hyaline plasma cells, but no giant cells. Mast cells are not abundant.

There is a rather peculiar distribution of polymorphonuclear eosinophiles in the lesion. They are not abundant but occur unexpectedly in groups in certain parts of the epidermis. The cellular exudate of a minute abscess may be entirely composed of them, or in wide areas none may be found. In the œdematous zone of the corium their distribution is irregular; only in certain places do they form almost a complete sheath about small blood vessels.

Levaditi preparation.—Sections 1 millimeter thick were fixed in 10 per cent formalin and stained by Levaditi's silver method.

In proportion to the degree of acute inflammation present, few treponemata were found. The organisms are most numerous within and about the hæmorrhages in the epidermis.

Yaw 2.—On September 2, this man received 0.75 gram of neosalvarsan intravenously; a rise in temperature and intense pain over the body followed.

September 5, three days after treatment, the lesions showed a distinct change. They were dry on the surface and showed a bright pink, healthy color instead of the yellow seropurulent discharge previous to treatment. There appeared to be a thin, unpigmented, transparent film of epithelium covering the papillary crests disclosing the bright color of the circulating blood beneath, and in the center a soft thin crust. The surface was otherwise clean, no pus to be seen. Under local anæsthesia Doctor Franco removed a small yaw, measuring 0.8 centimeter in diameter. Sections 1 millimeter thick were immediately fixed in 10 per cent formalin and in Zenker's fluid.

In gross the cut surface is gray and semitranslucent without the yellow tint of pus or the appearance of hæmorrhage. There is obviously less fluid exudate.

Microscopically there is very great change, most marked in the epidermis. On the surface is a thin layer of leucocytes and desquamated epithelium with beginning cornification. The evidences of exudation have almost completely disappeared; only a few straggling leucocytes caught in intercellular spaces remain in the site of previously great activity. The still deeply penetrating and interlacing columns of epithelium are compact and sharply outlined. Mitotic figures are numerous and though the cells, even of the basal layer, are larger than normal there is no appreciable excess of intercellular fluid. Large, branching pigment strands, while relatively sparse, are more numerous than in the previous section.

The papillæ of the corium present more evidence of the previous inflammation. Many of these are still greatly enlarged and turgid with fluid exudate. The interstices between collagen fibrils are filled with a clear, pink-staining, gelatinous material, like thick serum, within which are vacuoles. The blood vessels are not noticeably dilated, but the lymphatics are remarkably so. These areas contain relatively few cells; the majority are plasma cells and polymorphonuclears. There are appreciably more hyalinized plasma cells than were observed in the section before treatment.

The cellular exudate in the deeper portions of the corium appears the same as in the previous section, unless there is a relative increase in the number of polymorphonuclears and lymphocytes, and more hyalinization of plasma cells.

Levaditi preparation.—Sections stained by Levaditi's silver method show no treponemata. The pigment strands of the stratum germinativum stain conspicuously.

Yaw 3.—On September 9, the yaws were changed still more in gross appearance; since the 5th they assumed a dark slaty color, having lost completely their red tint. They were drier and beginning to form a scaly crust (hyperkeratosis), loosened about the margins.

Under local anæsthesia Doctor Franco removed a yaw measuring 0.7 centimeter in diameter. Cut sections show an irregularly thickened and firm epidermis, but the general consistency, especially of the corium, is softer than that of previous lesions. The corium has a slaty color.

Sections, microscopically, show a continued progress toward normal skin. Except for a slight excess of interstitial fluid in some of the papillæ there is a complete absence of evidence of acute inflammation. There are no polymorphonuclears, and both lymphatics and blood vessels have resumed their usual size. The epidermis is becoming rapidly readjusted. It is much thinner than in the previous sections and there is marked hyperkeratosis. Even in the deep epithelial pegs there is advanced keratosis, great central whorls of keratinized cells giving the appearance of small dermoid cysts. Individual epithelial cells are nearing the normal size and degree of compactness. There is a greater abundance of pigment in the form of large branching strands and of intra-epithelial granules situated in the stratum germinativum. There is also an abundance of pigment-bearing cells in the corium, which evidently gave the slaty tone noted in gross. The connective tissue of the corium is compact, but there is little change in the mononuclear exudate present in this layer. It remains abundant and composed of plasma cells and lymphocytes. Plasma cells are relatively less numerous than in previous sections, and hyalinized forms seem to be increased in number. There are less eosinophiles than previously noted and practically no polymorphonuclear cells.

Levaditi preparation.—Levaditi's method discloses no treponemata in the lesion.

HISTOLOGY OF THE YAW

The above observations on the histopathology of well-developed early yaws agree in most particulars with those of previous investigators. I have been more impressed perhaps than the majority by the degree of acute injury and reaction in the papillæ, especially in the earlier stages, and am of the opinion that the first local inflammation occurs in this portion of the skin, with secondary involvement of the epidermis. The presence of acute exudate and focal accumulation of polymorphonuclear cells in the corium of the youngest papule studied, a papule 2 millimeters in diameter from case 3, and the demonstration of treponemata in the perivascular tissues of papillæ in another fresh lesion (case 1), together with the recognition of an apparent necessity for the secondary eruption of yaws to begin with a localization of organisms from the circulating blood about smaller blood vessels of the skin, have urged upon me the acceptance of this conception of the beginning of the lesions.

The presence beneath the epidermis of treponemata of the species *Treponema pertenue* has not to my knowledge been observed before; and it is, indeed, a very curious fact that their distribution in demonstrable numbers is practically always limited to the epithelial layer. Here are certainly in later stages the optimum conditions for their growth, notwithstanding the fact that they may live in and be distributed by the circulating blood. This strict limitation in distribution is a noteworthy contrast to the disposition of the closely related *Treponema pallidum* which seems to find a more-favorable environment in connective-tissue spaces.

The purulent exudate in the epidermis is undoubtedly a reaction to the presence there of treponemata, and not a result of secondary invasion by pyogenic cocci from the surface, as was suggested by Unna who was not acquainted with the etiological agent of the disease, and thought probable by Siebert who, finding the treponemata only in association with the exudate, was inclined to think this a prerequisite for their localization. But the mass of leucocytic exudation and the greater number of miliary abscesses are situated nearest the basal layers of epithelium, and here treponemata are in greatest numbers and other organisms are absent. Nearer the surface treponemata diminish in numbers even in the miliary abscesses, and cellular exudate is abundant, while on the surface bacteria are present.

It appears in sections from case 1 that the margins of abscesses are extended by invasion of surrounding tissue by treponemata, and leucocytes accumulate about masses of these organisms lying within and about necrotic epithelial cells. With the destruction of the etiological agent all acute inflammation rapidly subsides. Finally, leucocytes and miliary abscesses and treponemata may be found in basal epithelium in young papules showing no evidence of surface infection.

Treponemata may be found in great numbers within the pockets of hæmorrhagic, serous, and purulent exudate, and they are less numerous in the dilated intercellular spaces of the epidermis and within degenerated epithelial cells. They can also be demonstrated within serous and cellular exudate about terminal vessels of papillæ. These organisms are the source of injury. In their presence epithelial cells become swollen or shrunken, their nuclei pallid or hyperchromatic and distorted. Many of them, becoming necrotic, are apparently dissolved as in miliary abscesses. Their injurious action extends to the vascular bed of the papillæ and the corium. Capillaries are dilated; their walls are injured, and hæmorrhage and cellular exudate ensue. With the accumulation of serum and cells within the epidermis the epithelium is further injured and its normal differentiation is arrested. There is a loss of pigmentation, and cornification is absent. Leucocytes and red blood cells are exuded upon the surface, fibrin is deposited, and serum oozes through the intercellular spaces. Along with this exudation epithelial cells are disrupted and thrown off prematurely. With surface evaporation a superficial scab is formed. In the meantime the epithelium of the basal layer actively multiplies and, as the papillæ project upward, the epithelial pegs correspondingly pierce downward. Mitotic figures are numerous in the irregular stratum germinativum, and the margins of this layer are for the most part definitely outlined, though occasionally ruptured by accumulating exudate within, and sometimes apparently by the growth of treponemata and resulting injury about the apical terminations of papillæ without. Not infrequently large branching pigment strands are seen in the basal layer ramifying among intercellular spaces, but isolated pigment granules are rare. Differentiation of the hair shaft is arrested, and one finds in the depths of hair follicles abortive shafts and hyaline epithelial pearls. Cells of sebaceous and sweat glands do not appear to be injured, although there is frequently a mononuclear exudate about the latter. Larger branches of nerves and erector

pili muscles seem as usual, and there are no vascular lesions deep in the corium. About the cellular accumulation in the corium there is a moderate proliferation of fibroblasts.

SPONTANEOUS HEALING

Nearly all the nodular cutaneous lesions of yaws in the course of time undergo spontaneous healing. After they have become well developed the process is a tedious one and may extend over a period of months or years, those on the palms of the hands and soles of the feet being especially chronic. Most of the macules and papules of the secondary eruption regress before they reach the frambœsiform stage. After the frambœsiform appearance is attained, regressive changes become manifest, such as drying of the surface and the formation of a thick keratin coat beneath which papillary projections covered by cornifying epithelium become more conspicuous and pigmentation of the part is increased.

Such a stage of arrested development and regression was represented in the lesions removed from case 5. The process of healing consists in the gradual disappearance of acute exudate (and undoubtedly of most treponemata) from the margins of the yaw. The epidermis becomes again compact and reassumes the differentiation of its cells, so that there are hyperkeratosis and increased pigmentation corresponding to the degree of epidermal hyperplasia present. Coincidently, there is a thickening of connective tissue within the papillæ, surrounding the blood vessels with a compact mantle of collagen fibrils. More gradually the exudate of the corium is removed so that with complete healing the surfaces become flat, but still a little rough and thickened. There is rarely complete ulceration of the surface with destruction of corium; consequently, scars do not frequently follow healing.

THE EFFECT OF INTRAVENOUS INJECTION OF NEOSALVARSAN ON THE LESIONS

Within forty hours after the injection of a therapeutic dose of neosalvarsan all treponemata demonstrable by Levaditi's method disappear from the early fully developed yaw. Within this time also practically all exudation in the lesions subsides. The blood vessels of papillæ are rapidly returning to normal, and the excessive fluid, especially within the epidermis, is lost, probably more by surface evaporation than by absorption, so that the lesion shrinks in size. With the loss of exudate the epidermis

becomes more compact and transparent, and the surface, now dry, assumes a bright pink color when the superficial scab is removed. The fluid exudate and most of the leucocytes vanish, leaving only a small cluster here and there, and numerous isolated ones lying in interepithelial spaces.

Most of the elevation of the early yaw is due to the fact that the epidermis is turgid with fluid and cellular exudate, and the initial shrinking and flattening result from loss of this exudate. The fact that the early yaw remains turgid for long periods before treatment presupposes a continuous injury to the vascular bed within the elongated papillæ with resulting dilatation of veins, capillaries, and lymphatics, and a continuous outflow of fluid and cellular elements. Following the destruction of treponemata the source of this irritation is removed and the vascular channels rapidly repair. This is the first change in the inflammatory reaction. In sections from case 1, forty hours after treatment, there were found some injured veins and capillaries plugged with thick fibrinous thrombi, a condition not observed in any untreated lesion. The dilatation of the vascular bed was also less marked.

With the restoration of blood vessels exudation is suppressed and the excessive fluid present in the epidermis is rapidly removed by surface evaporation and by absorption, resulting in the formation of a dry crust. Surface epithelium, in the early stages uncornified, and leucocytic exudate, including superficial miliary abscesses, largely compose the structure of the superficial crust, as is evident in sections. The remaining leucocytes not cast off in the crust are removed in other ways. Thus we find in sections that numbers of them are degenerated and necrotic. No doubt a certain proportion die, disintegrate, and become absorbed with fluid exudate. A larger proportion, however, are carried off bodily by large mononuclear phagocytes. Shortly following treatment the large phagocytes may constitute a conspicuous element of the lesion. They are most abundant in the papillæ, where they have engulfed numbers of leucocytes; but they are to be found wandering through intercellular spaces of the epidermis picking up polymorphonuclear cells wherever they find them. Even in the deeper exudate of the corium they are likewise prominent and active. They remove the leucocytes partly by intracellular digestion in situ and by transporting them through lymphatic channels to other places. Dilated lymphatics in papillæ are sometimes filled with them, each laden with disintegrating remains.

This evident widespread injury to polymorphonuclears resulting in local disintegration and rapid phagocytosis is worthy of some comment. One would not expect the mere subsiding of the inflammatory process to result in a rapid degeneration of leucocytes without the introduction of some injurious element. The sudden death and destruction of treponemata with the liberation of hypothetical toxic products could hardly account for it, for the injury seems to be limited to polymorphonuclears and to small lymphocytes lying in the center of immature follicles in the corium, and affects the former equally, whether in the epidermis or deeper in the skin. Necrosis of them tends also to be more marked about some of the smaller blood vessels of papillæ, although conspicuous also within the epidermis. The question naturally arises whether neosalvarsan itself may not exert a selective injury upon these cells, and this seems the more-probable explanation. In the fresh yaw, with continuous acute exudate through dilated and injured vessels, conditions seem suitable for a direct action of the drug on leucocytes in the tissues.

The thought arises that such local disintegration of polymorphonuclears may be favorable to the destruction of treponemata, for it is to be noted in sections of early untreated lesions that these organisms are diminished very greatly in number in older miliary abscesses where disintegration of leucocytes is proceeding. Phagocytosis of treponemata by these cells I have not observed, but they do appear to be effective against the organisms in some degree.

With the removal of fluid and cellular exudate the epidermis becomes more compact and transparent. The yellow opacity of the untreated fresh yaw is due to its content of leucocytes, and when these disappear the surface becomes gray and semitransparent, so that the bright color of the circulating blood is rendered visible, for in the early stage of healing there is very little epithelial pigment. In the corium, aside from destruction of leucocytes and, to a lesser extent, of lymphocytes about the vascular center of immature follicles, and active phagocytosis of their remains, little is to be observed following treatment. The removal of plasma cells and other mononuclear-cell exudate is a very gradual process and is not noticeable within the periods after which lesions were removed. There seems to be a greater degree of hyalinization of plasma cells and a diminution in the œdema. Very quickly (by the seventh day after treatment) pigment-containing connective-

tissue cells become numerous throughout the portions involved by exudate. At the end of this time definite reparative changes have occurred in the epidermis. Leucocytic and fluid exudate has almost completely disappeared and the epithelium has actively reassumed its normal differentiation in direct proportion to the degree of hyperplasia. Pigment granules have been reformed in a quantity greater than normal within and about the lower cells of the stratum germinativum. Grossly, the yaw has assumed a dark slate gray color; its surface is dry and covered by a crust of keratinized epithelium. The freshly cut surface presents also a brownish tint in the corium, which is due to the presence of a golden brown granular pigment within cells there.

With loss of exudate and by rapid keratinization, with probably diminished growth, the epidermis has reassumed a degree of thinness approaching the normal, and the papillæ are lower and more compact. Thus, very rapidly the surface becomes level with the surrounding skin, leaving a circumscribed pale or deeply pigmented spot to mark the site. After healing not infrequently hairs within these areas grow rapidly and to a greater length than the normal, indicating persistence of a growth stimulus, manifested also by more or less hyperkeratosis which continues for a while. In children pigmentation often does not occur so rapidly nor to such an extent as in adults, and the healed skin remains pale or even whitish.

In the older dry yaws such as those in case 5, relatively little change is to be noted three days after treatment. There are still a few leucocytes, both polymorphonuclear and mononuclear (epithelioid type), in small clusters and distributed singly. In the one preparation which we studied there was extremely active mitosis in the stratum germinativum—much more than in the tissue removed before treatment—but this may well be an accidental variation. There was also some destruction of leucocytes and lymphocytes in the corium. These lesions, however, were already, by spontaneous healing, in the stage of increased pigmentation and hyperkeratosis, and no treponemata were demonstrated in either preparation.

From the histological structure of these older lesions one gets the impression that treponemata which must be harbored there, though difficult to demonstrate, may be less accessible to the destructive action of intravenous neosalvarsan than those in the more acute lesions. This is indicated by the connective tissue thickening about the blood vessels of the papillæ and the

more compact state of the epidermis with its active hyperkeratosis. Certainly the exchange of fluids appears much less than in the stage of continuous serous exudation. The fact that the older lesions succumb less readily to treatment than the exuding early ones is not altogether due to the established histological changes in the former. It would seem an advisable precaution to continue treatment until healing of such lesions is complete.

SUMMARY

1. *Treponema pertenue* has been demonstrated by Levaditi's method in abundance in early yaws, not only within the thickened epidermis as heretofore observed, but also within perivascular connective tissue of the papillæ.

2. The lesions studied indicate that the secondary yaw begins with a localization of treponemata, from the blood, in certain papillæ, and from such points the organisms infect the epidermis, where conditions become more favorable for their growth.

3. Within forty hours after the injection of a therapeutic dose of neosalvarsan all treponemata demonstrable by Levaditi's method had disappeared from early yaws.

4. The remarkably rapid healing of secondary cutaneous lesions after injection of neosalvarsan consists essentially in an almost immediate suppression of acute exudation, and the removal of excessive fluid and cellular exudate by surface evaporation, by absorption, and by phagocytosis. The thickened epidermis quickly resumes normal differentiation with hyperkeratosis for a while until the epithelial layer becomes again of normal width and rapidity of growth.

5. It seems probable that neosalvarsan is destructive of polymorphonuclear leucocytes in the lesions, and this may favor the rapid disintegration of treponemata.

6. The older secondary nodular lesions have a more-permanent architecture, heal less rapidly, and probably offer greater protection to treponemata; consequently, they require more care in effecting a complete cure.

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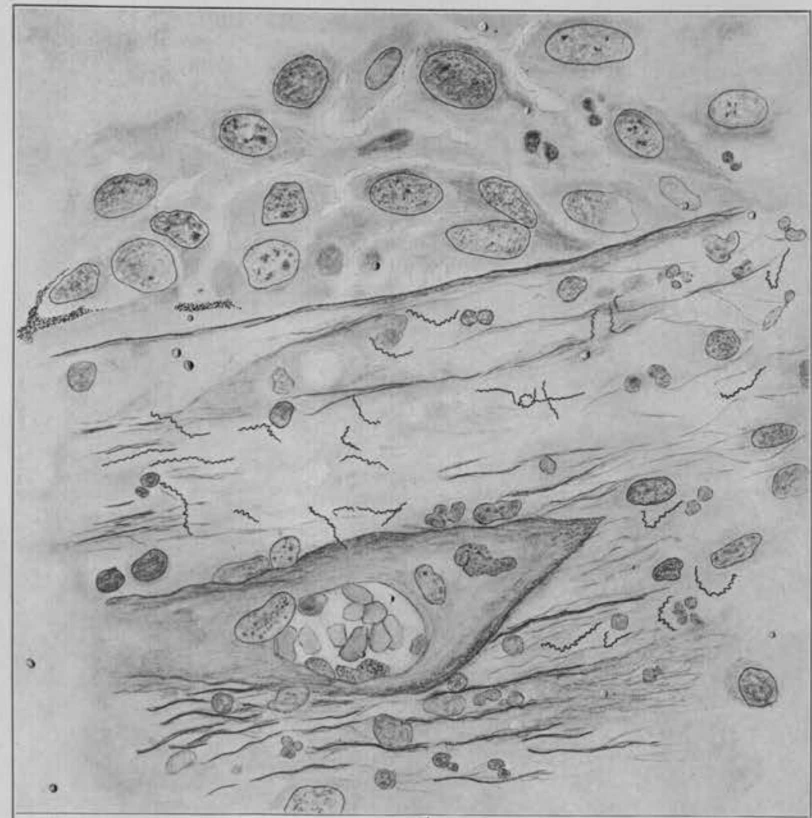
ILLUSTRATIONS



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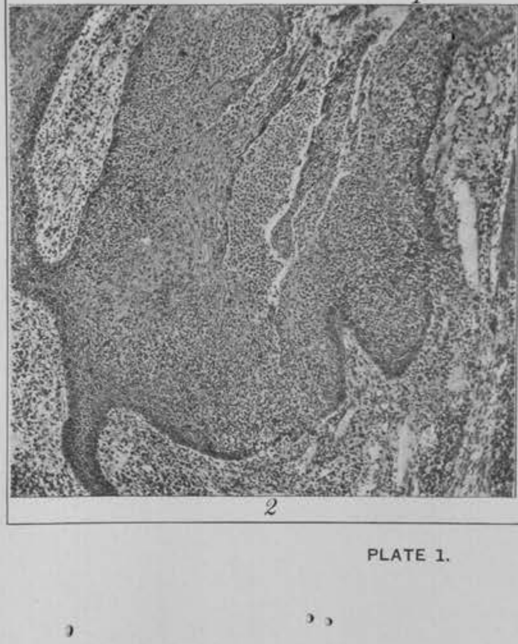

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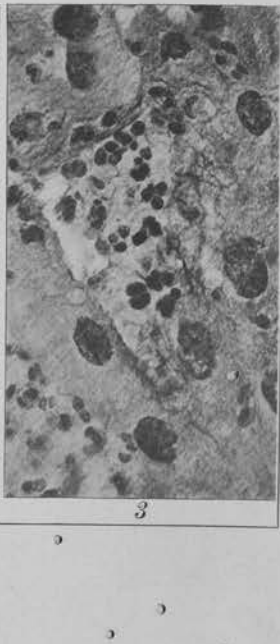

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PLATE 1.

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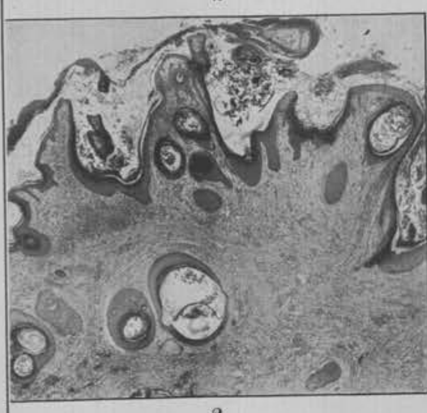

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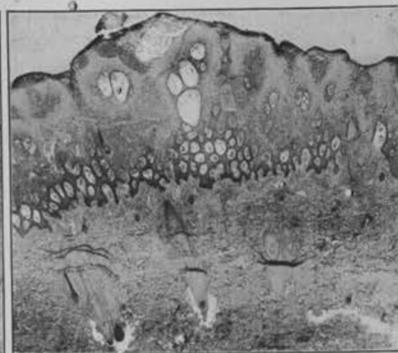

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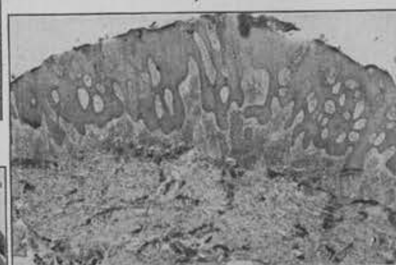

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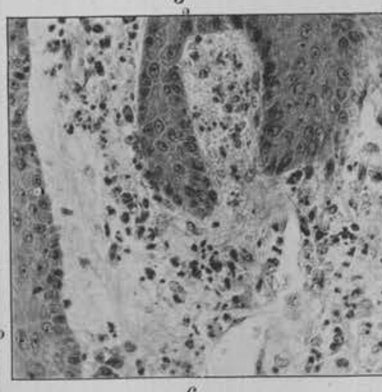

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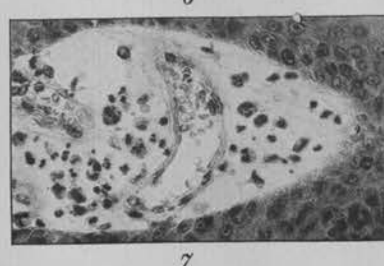

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PLATE 2.

SUMMARY CONCERNING THE CONTROL OF YAWS

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It is rather instructive to attempt to classify the important diseases of man, especially those of infectious origin, into two groups, one comprising the diseases that are eradicable or controllable by artificial means, and the other those that are non-eradicable. A disappointingly large number fall, at present, into the latter class. There are two very distinct and equally important groups of requirements for successful artificial control; one comprises the psychological factors and the other the scientific data. Operations based solely upon scientific data, even though very precise and complete, are beset with great difficulties and are foredoomed to partial failure. The information concerning the life cycle of a given parasite may be complete, and the measure for breaking this cycle may be very simple; but these facts do not offset the disadvantage of extreme indifference on the part of the infected individual.

From a psychological standpoint the disease it is proposed to eradicate must be instinctively very objectionable to the patient. In addition to this, the effective measures for its control must be of a nature that will appeal to all of the people concerned or, at the very least, be inoffensive to them. The spontaneous and hearty coöperation of the population is an invaluable asset.

In commencing the education of a community in public-health measures, much attention has been directed toward securing immediate spectacular results for the initial work. There is no disease which fulfills this condition so abundantly as yaws. It is the one infectious disease of man in which the striking benefit of therapy is just as evident to the casual onlooker as to the patient himself.

Yaws also amply fulfills the requirements of obnoxiousness, particularly as regards the loathsome lesions that develop around the mucocutaneous orifices. A single visit to a yaws clinic would surprise the most disinterested observer. The serious consequences of yaws are by no means limited to the granulomatous stage, for the late and tertiary stages produce marked pain and incapacitation. In the Loyalty Islands, Collin(2) reports that yaws is a grave menace; that in some villages of Lifou Island more than half of the children are covered with granulomata. Collin attributes the high infantile mortality of those islands to yaws and the other infections induced by it; he considers that Lifou itself is in danger of depopulation.

Left untreated, the granulomatous stage heals of itself after a few years; the mutilating tertiary lesions have been described from Africa by Howard.(3) The destructive lesions of the nasopharynx, known in Guam as gangosa, are generally considered to be a direct sequel of yaws. In Santo Domingo, the dread of yaws was particularly pronounced. Except for the intentional exposure of infants, people infected with yaws were studiously avoided. They were barred absolutely from the villages, not by government regulations, but by native custom. The first patient injected at our clinic there returned on his second visit practically cured. His first question was significant, being, "How soon may I enter the village?" Within the home, a small outbuilding was erected where the patient lived during the entire granulomatous stage, not being permitted in any of the other buildings. This primitive quarantine was apparently of some value in checking the spread of the disease within the family. These measures are certainly not practiced in the Philippines. Nevertheless, yaws patients do not mingle freely with the public. One may visit homes in villages where yaws is abundant without seeing any cases until inquiry or search is instituted, or until the opportunity for treatment is offered.

The requirement of coöperation could hardly be more readily satisfied than in the case of yaws patients. Indeed, in the early days of a clinic it is often oversatisfied. On commencing the work at Las Piñas, near Manila, we left a request for four patients to come to the Presidencia, only for examination and not for treatment. Before the appointed time, eleven presented themselves, and they brought a written list of seventeen others who requested that they be allowed to come. On some occa-

sions when no neosalvarsan was available, a few patients were requested to return later for examination only, and it was definitely announced to the other patients present that absolutely no treatments would be given and that they must not come to the next clinic. Nevertheless, they came in numbers, quietly and uncomplainingly, on the chance that some injections might be given.

In Santo Domingo we expected that the extremely superstitious people in the district where we worked, unaccustomed to medical attention, would be instinctively opposed to intravenous procedures. On the contrary, they referred to it as magic. Their confidence in the treatment was easily obtained. Patients accepted at the clinic for treatment were divided into two groups; namely, those who had just received their injections, and those who were awaiting their turn. The former at once designated themselves as the "cured cases." Occasionally a patient would present himself with nothing more than a malarial infection. Such patients, on being freely reassured and given quinine to take by mouth, often went home extremely disappointed at being denied an intravenous injection.

The acumen of the wholly untrained natives in the accurate recognition of the granulomatous stages of yaws facilitates field operations to a remarkable degree. They seldom overlook a case, and they do not tend to confuse it with other conditions. Nevertheless, it is urged that the equipment and personnel of a dispensary should not, as a general rule, be reduced to the barest working minimum. By the simple addition of a Wassermann outfit, contributions of value can be made to our knowledge of yaws and related diseases. It is well to be prepared to study some of the obscure conditions that exist in the isolated districts into which the treatment of yaws leads medical workers.

In the eradication of a disease, a distinct advantage is offered in those infections which are of the acute self-limited type and which produce a substantial immunity. This is illustrated very well by two diseases transmitted by mosquitoes; namely, yellow fever and malaria. The former has been eliminated in many regions and is even tending to die out spontaneously in some of its endemic zones. In the same geographical areas, the expenditure of considerable effort has brought malaria only under imperfect control. The lack of immunity results in the production of many chronic cases, and these serve as reservoirs of the infecting agent. However, chronicity of

an infectious disease is not necessarily a serious obstacle in attempting its control; the development of immunity is much more important, being in many cases almost an essential factor. This desideratum of immunity is at least partially fullfilled in yaws. The tendency to recurrence or reinfection after treatment is not great, amounting to about 5 per cent in practical work. Moreover, we have experimental evidence that the long-standing cases develop sufficient immunity to afford some degree of protection.

Clinically, it would seem that a certain proportion of yaws cases could be put, at least tentatively, in the rather unusual classification of a chronic self-limited disease.

A yaws clinic affords a distinct opportunity in the field of public-health nursing. The self-evident characteristics of the disease and its mode of attacking a community provide a clear, graphic illustration of the elementary precautions essential in personal hygiene. The enthusiastic coöperation of the patients makes them anxious to carry out any practical recommendations. The experience of having once had yaws teaches them the consequences of neglect and becomes an object lesson not easily forgotten.

In conclusion, we have no hesitancy in selecting yaws, without reservation, as the one outstanding disease of the Tropics through which the immediate confidence and enthusiasm of the people can be secured in public-health work. It fulfills in very fair measure the varied psychological and scientific requirements essential for the control of an infectious disease.

It seems reasonable to suppose that systematic effort, sustained over a period of a few years, would accomplish even the eradication of yaws from a given locality. There are many more or less isolated regions or individual islands in the Philippines where the feasibility of eradication could be tested experimentally.

Lastly, one's understanding of the two treponemal diseases cannot be completed by a study of either yaws or syphilis alone. Efforts in the control of yaws may properly be regarded as a step in the direction of that infinitely more-difficult problem, the control of syphilis.

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WOODS OF THE PHILIPPINE DIPTEROCARPS *

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THIRTY-ONE PLATES

INTRODUCTION

Previous to American occupation of the Philippines, in 1898, dipterocarps and dipterocarp forests were little known in the Islands. Under the Spanish régime timber exploitation had been largely confined to certain of the more-durable species of other families, such as narra (*Pterocarpus* spp.), tindalo [*Pahudia rhomboidea* (Blanco) Prain], molave (*Vitex parviflora* Jussieu), and others of the scarce but valuable woods, a fact which was the logical outcome of conditions then prevailing. In those days durable hardwoods were comparatively abundant and easy of access in open places near the towns. Modern sawmills were unknown, and logs were of necessity converted into lumber with the expenditure of excessive man and animal power, employed under primitive conditions. Finally, only the more durable of the native woods seemed worthy of exploitation, since consumption was confined to the Islands where deterioration, particularly that resulting from insects and fungi, is very rapid. As a result the heavier and most durable of the dipterocarps, such as yakál (*Hopea* spp., *Shorea* spp., and *Isoptera* sp.), giho[1] [*Shorea guiso* (Blanco) Blume], and manggachapuí (*Hopea acuminata* Merrill and other species) found their way into the local markets, while such of the lighter lauaans[2] as were lumbered were used mainly for canoes and dugouts or, occasionally, as floats for the heavier woods.

* Contribution from the New York State College of Forestry, Syracuse University, Syracuse, New York.

[1] This word is often written "guijo." The phonetic method of spelling is used throughout this work and an effort made to write the names as they are pronounced by the natives.

[2] The term "lauaan" was corrupted into "lauan" by the Spaniards, and subsequently adopted by the Bureau of Forestry under the American administration. Its meaning is not well understood, although the word seems to be closely related to "laua" or "laua-laua," meaning soot. When used alone, lauaan signifies any soft, light dipterocarp of the genus *Shorea*, *Parashorea*, or *Pentacme*.

With the arrival of the Americans the Bureau of Forestry was again revived. This resulted in an immediate and general inventory of the forest resources of the Islands and the enactment of measures which were intended to stop unnecessary timber destruction by land squatters and kaiñgin makers.[3] Whitford[4] in 1909 pointed out for the first time that the real forest wealth of the Philippine Islands lies in their dipterocarp forests, which make up about 75 per cent of the standing timber. Following the publication of his studies several sawmills of modern type were established, and at the present writing there are no less than twelve modern plants, each with a daily capacity ranging from 25,000 to 100,000 board feet. As a result the Philippine market has been flooded with woods that were little or wholly unknown before. Importation of structural timber from Australia and the United States has decreased, and to-day appreciable quantities of Philippine lumber are being exported to the United States and our neighboring countries.[5]

PURPOSE OF THE STUDY

Much confusion has arisen in the utilization of native dipterocarp woods owing to their sudden influx into the lumber markets of the world. Dipterocarp timbers intergrade but present wide extremes in strength, durability, beauty, and figure of grain, and it follows that some are more desirable than others, at least for special purposes. It is out of the question to expect the ordinary lumber grader or dealer to distinguish the wood of closely related species. In fact, errors of substitution are often pardonable or justifiable in that the structural variation is so slight as to have little or no bearing on the mode of utilization.[6] Few lumbermen, for instance, know the difference between red lauaan and tangile, or giho and yakál, or manggachapuí and palosapis, to say nothing of the numerous

[3] A "kaiñgin" is a temporary clearing in the forest used for crop production by the natives. The trees are felled, allowed to dry, and subsequently burned during the dry season. The kaiñgin system is largely responsible for the extensive grasslands that are found throughout the entire Archipelago.

[4] Whitford, H. N., The composition and volume of the dipterocarp forests of the Philippines, Philip. Journ. Sci. § C 4 (1909) 699–725.

[5] See P. I. Bur. Customs 1913 et seq.

[6] The lumber of tangile and red lauaan, which are among the most important dipterocarps, is often mixed indiscriminately and marketed under the trade name of "tangile."

species of lauaans. But in the inventory and development of the natural resources of the Islands, finer distinctions must be drawn. Woods which superficially seem alike may prove to differ widely in their physical properties, when more thoroughly studied. Closer utilization entails an accurate knowledge of the anatomical features and physical properties of the wood of the various forms. The following studies, based on gross and minute anatomy, aim to distinguish the commercial species. This has never been attempted previously, and the present work is in the nature of a preliminary survey.

In approaching the subject it has seemed desirable first to discuss the wood of a typical dipterocarp at some length, since this would not only acquaint the reader with the general features of the timbers of this family, but at the same time would offer a logical starting point for the remainder of the study. For the purpose in view, it was thought that *Parashorea malaanonan* (Blanco) Merrill[7] (*Parashorea plicata* Brandis) would best serve, owing to its wide distribution and abundance throughout the Islands and the fact that its wood seems to incorporate best

[7] Bagtikan (*Parashorea malaanonan* Merrill) (Plates 1, 2, 6, 7, 8, 22) is one of the largest of the dipterocarps and is found on all the large islands of the Archipelago from northern Luzon to Mindanao. In virgin forest it is not uncommon to find trees 40 to 50 meters in height with a diameter at breast height of 2 meters. As is characteristic for the trees of this family, the bole is tall and often unbranched for 20 or 30 meters and bears the crown far aloft. Under forest conditions the latter becomes much restricted.

Parashorea malaanonan is one of the faster-growing dipterocarps and, as is often the case in such trees, avoids habitats like the western part of Luzon, where there is a pronounced dry season. It undergoes suppression well, but the growth is then much restricted. According to Brown and Matthews, Philip. Journ. Sci. § A 9 (1914) 475, those trees which grow in dense forests undergo a long suppression period in contrast to those which are exposed, and require fully twice the time to reach any diameter up to 65 centimeters. Trees 20 centimeters in diameter average twenty-three years of age when grown in the open, while forest-grown specimens of like diameter average approximately one hundred six years.

Further researches have also shown that bagtikan exhibits periodical fluctuations of growth intensity. There are two distinct periods of slow and two of rapid growth. The first period of inhibited growth occurs during the height of the dry season when transpiration is at a maximum, the second during the mid-rainy season when the sky is overcast during a large portion of the day. The first optimum is attained during the earlier part of the rainy season and is followed by a second after the close of the rainy season when insolation is at a maximum.

those anatomical features which may be considered as typically dipterocarp. Furthermore, *Parashorea malaanonan* has been the subject of numerous studies of growth and management in the Archipelago, and a detailed study of its anatomical structure may help to solve problems of its utilization.

The remainder of the present study consists in a detailed enumeration of the gross and minute anatomical features and physical properties of the wood of the other commercial dipterocarps,[8] employing *Parashorea* as a foundation for the technical discussion. The anatomical departures will be noted at length, and it is hoped that the keys which accompany the study will prove of diagnostic and practical value.

I take this opportunity to express my sincere gratitude to Dr. H. P. Brown, head of the department of wood technology at the New York State College of Forestry at Syracuse University, Syracuse, New York, under whose department this piece of work was performed. Doctor Brown tendered invaluable advice and criticisms throughout its preparation.

ANATOMY OF THE WOOD OF PARASHOREA MALAANONAN (BLANCO) MERRILL

GROSS FEATURES OF PARASHOREA WOOD

The wood of *Parashorea* is numbered among those of the softer dipterocarps and is moderately hard and moderately heavy (specific gravity, 0.594).[9] The sapwood, which is narrow and seldom over 2 to 3 centimeters in thickness, is grayish white when first exposed, but often assumes a dark brown hue[10] in striking contrast to the paler, reddish brown heartwood.

[8] Seventy-two species of Philippine dipterocarps are known to date, grouped in nine genera. Of these, some twelve may be considered as strictly commercial species and about an equal number are of more or less importance locally. See Foxworthy, F. W., The Philippine Dipterocarpaceae, Philip. Journ. Sci. § C 6 (1911) 231; 13 (1918) 163.

[9] Determination based on mature trees from different localities; wood with moisture content of approximately 8 per cent.

[10] The darkening of the sapwood of *Parashorea* upon exposure to the air is due to certain chemical (oxidative) processes which take place in the wood. The vertical and ray parenchyma cells remain living as long as they are a part of the sapwood, and contain varying amounts of organic material. When a tree is felled and optimum conditions of temperature and humidity prevail the enzymes which are present in these living cells bring about chemical changes in their contents with a resultant darkening of the tissue. See Baily, I. W., Bot. Gaz. 50 (1910) 142–147.

Seasonal rings are wholly wanting in spite of the fact that growth intensity in the tree is known to fluctuate appreciably at different seasons. The wood is very homogeneous, of coarse even texture, and distinctly cross grained.

In cross section the vessels appear as large pores, which either are solitary or exhibit a tendency to group themselves in rounded clusters of three to six or string out in rows of three to fifteen obliquely to the wood rays. In the main the ducts are open, but occasionally tyloses are present, which occlude the vessels as reddish cystlike ingrowths. The most conspicuous feature of the section, however, and one which is of diagnostic value for all dipterocarps, is the presence of resin cysts, which in this species are filled with a white amorphous deposit and stand out as white dots against the darker opaque background of woody tissue. The resin cysts of *Parashorea* exhibit the same arrangement as the traumatic resin cysts of conifers; that is, they occur in single rows, which extend tangentially as arcs, concentric with the growth rings.[11] The radial arrangement of the rows is irregular; they occur at intervals varying from a few millimeters to several centimeters. Isolated cysts are commonly present, but they are smaller and not readily discernible with a hand lens. Tetragonal crystals of calcium oxalate may be seen with the help of a magnifier as occasional whitish dots bordering wood rays. When viewed with the naked eye, in addition to the pores the wood rays may be seen as rather fine reddish lines which extend radially through the wood. Their color is traceable under higher magnification to infiltration products contained in the ray cells. Only the larger rays are discernible at this magnification; narrow rays, too small to be visible, are interspersed between the larger ones.

The remainder of the cross-sectional area is occupied by wood elements too small to be discerned individually at low magnification. Evidence of a division of labor is to be seen, however, in that the pores are surrounded by lighter areas of tissue which had at least some part in the transportation of water and solutes while included in the sapwood. The darker areas, at some distance from the vessels, are composed of cells that perform purely the mechanical function.

In tangential section the vessels are conspicuous, owing to their large size, and appear as articulated tubes, occluded in part

[11] Complete rings of resin ducts are very rare in the dipterocarps, if they exist at all.

by reddish tylosic growths. The vessel segments, which arise from separate initials in the lateral meristem, are distinct and when viewed with a hand lens are seen to be clothed with smaller cells of similar length, the so-called tracheids. The tracheids and wood parenchyma give rise to the lighter areas about the pores as seen in cross section. The wood rays appear in sectional view as fine lines not over 2 millimeters in length.

Radial sections are striking in appearance. The relatively high wood rays are now seen in surface view against the background of other tissue and stand out as ray flecks which reflect the light differently, causing the wood to be lustrous. The vessels extend vertically and appear as in the tangential section. Owing to the interlocking grain of the wood a "ribbon" figure is produced, which is sometimes more distinct than that of *Swietenia mahagoni* Linnæus. This feature of the dipterocarps, as previously noted, is exploited by lumbermen, who in sawing their logs radially or nearly so not only obtain boards with enhanced figure, but at the same time reduce possible warping in seasoning to a minimum. The best ribbon effect is obtained when the wood rays are cut at an angle of 10° to 25° to the surface of the board.

MICROSCOPIC FEATURES OF PARASHOREA WOOD

Two methods of procedure are open in discussing the microscopical structure of wood. In the one case the tissue itself may first be dealt with and its several anatomical features enumerated at length, and following this the various elements that compose the wood may be obtained by maceration and their structure studied in detail. This order may often be reversed to advantage, since the structure of wood—that is, the arrangement of the cells that compose it—can best be interpreted when the intimate morphological features of its individual elements are understood in advance. It is then a comparatively simple matter to study such elements in the three planes of section and to trace their topography in the stem. It has seemed desirable here to follow the second plan.

PROSENCHYMA VERSUS PARENCHYMA

The woody elements of *Parashorea*, as is the case in all woody tissues, fall naturally into two groups—the prosenchymatous and the parenchymatous—between which no hard and fast line can be drawn. In general, prosenchyma consists of elongated, thickened, dead cells with strongly lignified walls and pits which are usually bordered. Prosenchymatous tissue performs two

functions in the economy of the plant; namely, conduction and mechanical support. On the other hand, parenchyma cells are thinner walled and less attenuated (often rectangular in section) and exhibit simple pits. While the walls often respond to lignin reactions, they are seldom as strongly lignified as those of the prosenchyma. The parenchyma cells of wood act as storage organs and function as long as they are a part of the sapwood; in addition, those composing the wood rays likewise are concerned in radial conduction.

The prosenchymatous tissue of *Parashorea* consists of vessels (tracheæ, pores, ducts), tracheids, and libriform fibers and extends vertically (longitudinally) in the wood. The parenchymatous tissue on the other hand consists, in part, of cells that have their long axes arranged vertically, the so-called vertical parenchyma, and in part of ray parenchyma which makes up the wood rays. Either type may give rise to idioblasts through intracell formation of crystals. In addition, the epithelial cells surrounding the resin cavities must be considered in the light of parenchyma, but whether they are of the same origin as the vertical parenchyma cells is open to argument, as in the case of the conifers.

ELEMENTS OF PARASHOREA WOOD

Vessels (*tracheæ, ducts, pores*).—(Plate 2, fig. 8.) The vessel segments are of a prosenchymatous nature and are the most conspicuous elements in macerated material owing to their large size. They appear as cylindrical structures with "tailed" ends, which taper abruptly from alternate corners, and vary in diameter and length, respectively, from 108 to 317 μ (average, 236) and 147 to 550 μ (average, 465). As in other woods their width is in inverse proportion to their length. A round perforation, opening out from either end, indicates the original interdependence of the segments as they occurred in vertical rows in the wood.

The walls of the vessel segments are comparatively thin, measuring from 3.6 to 7 μ in thickness, and are marked with bordered or semibordered pits, which conform to three types and owe their orientation to cells contiguous to the segment. Where tracheids abut on the radial or tangential walls, vertical or twisted bands of small, typically bordered pits result. The larger pits with vertical grouping, which at first glance appear to be simple but are in reality semibordered, indicate the position of vertical parenchyma cells which are coterminous to the

segment. Here and there the radial walls are latticelike or reticulate in appearance, owing to an aggregation of the larger, semibordered pits where a wood ray came in contact with the vessel. The ends of the segments frequently exhibit more abundant pitting, because the tips of neighboring cells (tracheids of the length of the segment) interlace in such a manner as to bring the maximum number in contact with the wall of the vessel.

Tracheids.—(Plate 2, figs. 10 and 11.) Tracheids are prosenchymatous elements whose primary function, like that of the vessels, is conduction. When isolated they appear as slender, elongated, generally twisted cells with rounded ends and lateral walls, which are abundantly equipped with numerous, small, bordered pits leading to neighboring tracheids or vessel segments. Occasionally the larger, semibordered pits similar to those of vessel segments are found on tracheid walls where the latter are contiguous to vertical parenchyma of wood rays. The tracheids of *Parashorea* measure from 352 to 800 μ (average, 420) in length and 14 to 30 μ (average, 24) in width and, as will be pointed out subsequently, arise from the same cambial initials as the vessel segments. In contrast to the latter, however, their walls are about half as thick and are comparable to those of the parenchyma cells.

Libriform or wood fibers.—(Plate 2, fig. 1.) The final type of prosenchyma in the wood of *Parashorea*, the libriform fibers,[12] are longer, thicker walled, and more attenuated than the tracheids and are to be regarded as typical mechanical elements. They measure from 1,130 to 2,390 μ (average, 1,690) in length and 14 to 31 μ (average, 22) in width, with walls 3.5 to 7.5 μ in thickness, and taper gradually from the center. As a rule, the ends are smooth but occasionally become serrated or forked where the fibers are pressed together. Owing to the mechanical nature of these cells, the pits on the vertical walls have degenerated into slitlike openings, which extend vertically in the cell wall and appear in the mature elements as more or less vestigial structures. Gummy deposits sometimes leach through such pits from contiguous parenchyma and partially occlude the lumina.

Vertical parenchyma (wood parenchyma proper).—(Plate 2, figs. 6 and 7.) In macerated material the vertical parenchyma

[12] Elements intermediate in form between tracheids and libriform fibers, the so-called fiber tracheids, are wanting in *Parashorea*.

cells appear as isolated rectangular or triangular elements, or in short series of three or four with tapering terminals. In the latter case the rows resemble superficially the septate fibers, but differ in their simple pitting and in the nature of their cross walls.[13] Their fibrous shape is indicative of the origin of the series in the cambium from primordial cells of the same type as give rise to vessel segments and tracheids. The features that separate the vertical parenchyma and prosenchyma arise subsequent to cell division in the lateral meristem and are a result of normal development in the maturation of the elements.

Both the end and the lateral walls of the parenchyma are abundantly provided with simple pits which vary in contour, depending on the nature of the neighboring elements, from round to ovoid or deltoid. The individual cells measure, respectively, 56 to 216 μ (average, 124) in length and 12 to 36 μ (average, 24) in width. As in the case of the vessel segments, it follows that the greater the diameter of the individual elements, the shorter the length. In *Parashorea* the lumina are commonly filled with gummy infiltration products.

Epithelial cells.—(Plate 2, figs. 4 and 5.) The epithelial cells are found in immediate proximity to the resin cavities and, as in the case of coniferous trees, are undoubtedly intimately concerned in the production of resin. In macerated material they usually occur in aggregates of a half dozen or more and appear as quadrate or rectangular cells which grade off into typical wood parenchyma. Their relation to the vertical parenchyma is still further accentuated by the similarity of their walls in thickening, pitting, and in their chemical nature. In *Parashorea* they measure from 10 to 30 μ in width and from 10 to 43 μ in length.

Ray parenchyma.—(Plate 2, fig. 3.) Ray parenchyma, as the term implies, is found in the wood rays and makes up the total volume of these structures, as in all hardwoods. The ray-parenchyma cells are very similar to the vertical parenchyma in shape, and in the nature of their cell walls and in macerated material are very difficult to distinguish from the latter. Only in the case of the marginal ray cells, which assume the shape of a triangular prism, can identification be positive,[14] although

[13] The cross walls of septate fibers are thinner and differ chemically from the vertical walls, while those of the parenchyma are comparable in every respect.

[14] The "end" cells of the vertical rows of parenchyma are pyramidal.

the ray cells are somewhat larger (36 to 126 μ in length and 10 to 54 μ in height) and generally contain infiltration products in larger amount than do the vertical cells. As in the other features, the rule for cell dimensions applies; namely, cell height varies inversely to cell length.

Crystallogenous idioblasts.—(Plate 2, fig. 2, and Plate 7.) Crystallogenous idioblasts are abundant in the macerated wood of *Parashorea malaanonan* (Blanco) Merr., either as isolated cells or in short rows, and they may arise from either the vertical or the ray parenchyma, though more commonly the former. When arising from the vertical parenchyma, the cells of a vertical row become further segmented by the septa into a beadlike or catenate string of compartments, twenty-five or more in number, in each of which a solitary tetragonal crystal of calcium oxalate is formed. The new cross walls thus formed are typically parenchymatous in nature, both in pitting and in thickness, and the identity of the original parenchyma cells is completely lost. Such idioblasts are to be regarded as depository organs, and the calcium oxalate is undoubtedly a waste product in plant metabolism.[15]

The idioblasts that arise from the ray parenchyma are not so abundant nor so conspicuous in macerated material as are those of the vertical type. As in the case of the longitudinal rows they are formed through subsequent septation of ray cells into from two to five compartments, in each of which a tetragonal crystal forms. The crystals are smaller as a rule than those contained in the vertical idioblasts.

DISPOSITION OF THE ELEMENTS

The preceding paragraphs have been devoted to a study of the individual elements of *Parashorea* wood as they appear in macerated material, and indicate the wide departures in cell types that are correlated with varying function. The disposition of the different elements in the cell aggregate that we know as wood may now be studied to advantage at higher magnifications and the significance of the grouping more readily understood. In the following pages the wood of *Parashorea malaanonan* is discussed in detail as it appears in the three planes of section.

Cross section.—(Plates 3, 4, and 22.) In cross section at magnifications of 50 to 100 diameters, the vessels stand out very conspicuously, owing to their abundance and their large size, and appear as rounded pores that are sharply delimited at the margin

[15] Calcium oxalate crystals are common in the tissue of the higher plants, particularly in leaves. They stain readily with methylene blue.

by the encirling walls. As previously noted, they are either solitary and assume a more or less circular contour, or in sequence and contiguous in strings of two to five, and somewhat flattened at the points of contact.[16] The diameter varies from 72 to 317 μ, but as seen in mass the impression is that of uniform size since it is only in the groups or in an occasional solitary cyst that the dimensions are appreciably restricted. The coarse texture of the wood of *Parashorea malaanonan* is traceable to the prevailing large size of the vessels, which make up about 32 per cent of the wood volume.[17]

Here and there the pores are occluded with tyloses which are infiltrated with organic material and appear as vesiculate plugs neighboring wood rays. As pointed out by other investigators, these have their origin in the large pits that separate the ray parenchyma from the vessels, and have an important bearing on the durable qualities of the wood.[18] In *Parashorea* they arise, as a rule, from the uniseriate rays, but are not sufficiently abundant to be a conspicuous feature.

Tyloses usually occur where wood rays are contiguous to vessels and, although a conspicuous feature of heartwood, are formed while the elements are still a part of the sapwood. They are of great practical significance in the utilization of wood, since they inhibit the movement of air and moisture in the tissue, both of which are necessary for fungal growth. *Hopea plagata* (Blanco) Vidal, *Isoptera borneensis* Scheffler, and various species of *Shorea* have highly developed tyloses and are among the most-durable dipterocarp woods, while the reverse applies to *Shorea eximia* Scheffler and species of *Pentacme* and *Anisoptera*.[19]

Coursing between the pores in a radial direction and making up from 11 to 17 per cent of the wood volume[20] are bands

[16] The tendency toward grouping in oblique lines, which is to be noted with a pocket lens, is obscure at higher magnifications.

[17] The volumetric data were obtained from photomicrographs by cutting out the elements concerned and comparing their weight to the total weight.

[18] The causes underlying the formation of tyloses are not well understood, but it is generally conceded that their formation is due to heightened osmotic pressure in the parenchyma bordering vessel segments which results in the "enlargement" of the middle lamella. Cystlike structures result in the vessel cavity, which may continue their growth until the lumen is completely occluded.

[19] See Gerry, Eloise, Tyloses; their occurrence and practical significance in some American woods, Journ. Agr. Res. 1 (1914) 445–469.

[20] The ray volume varies directly as the density. See Myer, J. E., The ray volumes of the commercial woods of the United States and their significance, Journ. of Forestry, Washington, D. C. 20 (1922) 337–571.

composed of elongated cells with oblique end walls and dark brown contents and conspicuous because of their darker color. The larger rays, which are multiseriate and consist of four to six rows of cells, pursue a straight course across the field except for slight deflections where they are contiguous to or approach the larger pores. At such points they curve slightly, while the pores are somewhat flattened on the side of contact. Where vessels abut on opposite sides of the ray, the latter becomes very much restricted where it extends between them.

Interspersed between the larger bands are smaller rays which, at the start at least, consist of but a single row of cells comparable in every way to those which compose the multiseriate type. The course of the uniseriate rays across the field is much more irregular than that of the multiseriate rays, since they curve around the pores that lie in their course and are not of sufficient size to cause them to become flattened. As will be pointed out subsequently, the narrow rays of the cross section are in part uniseriate throughout their vertical length, and in part the margins of multiseriate rays which happen to be included in the plane of section. It is from the uniseriate rays that the tyloses of the vessels are mainly derived. The light areas of small cells about the pores are a feature of many tropical woods and they consist, in *Parashorea*, of tracheids and vertical parenchyma (Plate 22). The tracheids, like the vessels, are organs of conduction and mechanical support, and are strictly vasicentric. They are found only in regions contiguous to vessel walls and occur in the angles between coterminous vessels, or vessels and wood rays (Plate 3).[21] The paratracheal or vasicentric parenchyma, on the contrary, separates the libriform tissue from the vessels and tracheids and may adjoin the ducts directly or abut upon the tracheids neighboring them. It performs mainly the storage function and is in intimate connection, on the one hand, with the ray cells from which it obtains food for storage and, on the other, with the vessels direct or through the intervening tracheids into which it pours food in solution at periods of growth optima. Tracheids and vertical parenchyma together constitute from 14 to 19 per cent of the wood.

The libriform fibers (wood fibers), which are the principal mechanical elements, make up the background for the other cells, and form from 35 to 40 per cent of the volume of the

[21] In this plate the tracheids to the right of the uniseriate ray are in contact with the vessel wall above or below the plane of section.

wood. As viewed in cross section they appear as small, thick-walled elements of varying size [22] and narrow lumina, and are grouped compactly in the areas not restricted to conduction and storage. Libriform fibers arise from the same fusiform cambial initials as vessel segments and tracheids but, as they mature, they elongate and push in between one another, and thicken their walls until only a narrow lumen remains. Owing to the pressure resulting from their elongation, they assume an oblong, rounded, or polygonal form in cross section. Here and there a radial row consists of units of uniform size, indicating their common origin from one initial in the lateral meristem.

In places the intervals between wood rays are solidly banked with libriform fibers and form extensive tracts of tissue whose function is purely mechanical, but often the continuity is broken by the pores with their envelope of tracheids and parenchyma or by parenchyma alone. In the latter case the cells occur in the midst of the libriform fibers as isolated units [23] which may be identified by their thin walls, or in short tangential strings that extend out laterally from the wood rays. Here and there a cell bordering a ray enlarges somewhat and becomes modified into an idioblast, which is conspicuous owing to the angular crystal that it contains. The parenchyma of *Parashorea* is, in the main, paratracheal, but a tendency toward the diffuse condition is expressed through the invasion of the libriform tissue by individual cells or tangential strings.

As previously noted under microscopic features, the resin ducts are borne in tangential rows, which occur at intervals varying from a few millimeters to several centimeters, more rarely solitary. At higher magnifications an affinity with the larger pores is expressed, which is as yet unexplained since the rows occur in areas where the vessels are numerous and bound the resin cavities on either side. The resin cysts are intercellular spaces of schizogenous origin, as in the Coniferæ, and are embedded in strings of parenchyma connecting the wood rays. They originate in the cambium as areas of parenchymatous cells, the innermost of which separate at the middle lamella and pull apart as the tissue matures. In *Parashorea* the first

[22] The varying size is to be explained by the fact that the fibers are long-attenuate and are cut at different heights in the cross section.

[23] It follows that a living cell could not exist if totally surrounded by prosenchyma (dead) tissue. Parenchyma cells, which in cross section appear to be surrounded by libriform fibers, are in contact with ray parenchyma above or below the plane of section.

indication of the formation of a resin cavity is a fissure in the tissue, which results from the splitting of the middle lamellæ between the four cells (Plate 5, fig. 1) and the subsequent separation of the elements. The process may continue tangentially (same plate, figs. 2 and 3) until other parenchyma cells are involved and cavities of considerable extent are formed, or the mature duct may have but the four epithelial cells, in which case it is usually isolated. The resin cavities of *Parashorea* measure from 30 to 130 μ tangentially and are surrounded by from four to twenty secreting cells.

In cross section the epithelial cells bordering the cavities differ little from the surrounding parenchymatous tissue. They are somewhat arched on the distal face owing to the absence of contiguous cells on that side and a resultant lack of tissue tension but, in general, retain the tabular form of the neighboring parenchyma. Strictly speaking, the epithelium consists of but a single layer of cells which lines the resin cavity and is followed peripherally by one or more layers of parenchyma, the first of which is usually more or less transitional. The disparity in form and appearance which distinguishes the epithelium from the bordering tracheids in conifers is not evident in dipterocarp woods.

When observed in the longitudinal plane the wood of *Parashorea* assumes a very different aspect, since the vertical elements are now seen from the side and features appear which are not evident in the transverse section. These may now be discussed to advantage and should serve, when considered in connection with those of the cross section, to render comprehensible the microscopic structure of *Parashorea* wood. Two sorts of longitudinal section are possible; namely, one parallel to the wood rays, known as the radial section, and one at right angles to the rays and tangent to the growth rings, the tangential.

Radial section.—(Plate 6.) In thin radial section the composite character of the vessels is readily apparent, since they appear as interstices or, where the radial walls chance to be included, as punctate fields in the tissue which are bounded laterally by articulated walls and extend longitudinally in the wood. Constrictions occur at intervals and delimit the various segments, which vary appreciably in length not only in different vessels but also, for unaccountable reasons, in the same duct. The shorter segments are wider than long and are often barrel-shaped, while the other extreme is represented by the long cylindrical form. All grada-

tions between these types occur, since the rule covering cell dimensions likewise applies in this instance: vessel-segment width is inversely proportional to vessel-segment length. Where the section is not median to the duct, cross walls appear to separate segments owing to the constriction of the latter in the region of the pores, an illusion which is readily apparent, however, when thicker sections are prepared.

As previously pointed out, the light areas that bound the vessels laterally consist of tracheids and parenchyma or parenchyma alone. The characters of these two types of cells are now seen to better advantage, and they can be separated without any trouble. The parenchyma, which is always associated with the vessels, appears as rectangular cells several times longer than wide, but much shorter than the neighboring vessel segment. The tracheids, where present, are contiguous to the duct, are much longer than the parenchyma cells, and are characterized by rounded ends. Evidence of their origin from the same cambial initials as vessel segments is to be found in the fact that they approximate the latter in length, and transition forms between the two types are not uncommonly seen at this magnification. As in the case of the vessels, the walls appear punctate from the numerous bordered pits.

Crossing the vessels at right angles are the wood rays, which appear as broad bands of muriform parenchyma consisting of many tiers of superposed cells whose lumina contain reddish brown organic material of a gummy nature or, occasionally, crystals. In *Parashorea* the rays are of the type designated as heterogeneous, since the last series of the upper and the lower margins are higher and shorter than the others, although exhibiting similar pitting and content. In addition, rows of high cells are occasionally interspersed in the ray, but as a rule the interior appears quite homogeneous, consisting of seried ranks of quadrangular cells.

Owing to the nature of secondary thickening in trees the rays pursue in general a radial course in the wood but, as previously pointed out, are deflected more or less at the vessels, particularly the uniseriate rays. Consequently, in sections that are strictly radial and of necessity median here and there to ducts, the rays are interrupted by the vessel cavities but continue again on the other side. This results in a series of ray flecks extending across the grain of the wood which have originated from one ray. Furthermore, since new rays arise in response to necessity as

the periphery of the tree increases, it follows that ray flecks may begin or run out at any point in the wood, depending on the orientation of the section.

Occasionally, a row of resin cysts may be seen running longitudinally in the wood and appearing as a series of cavities surrounded and connected by parenchyma. The first impression is that a resin duct has run out of the plane of section only to reappear at another point, but this idea can be dissipated by reference to cross sections where it is not uncommon to find masses of parenchyma in place of the so-called resin ducts. The resin cavities of *Parashorea* consist of a series of vertical cysts separated by masses of parenchyma and are comparable to the traumatic cysts of the Coniferæ.

The epithelial parenchyma bordering the resin cysts, as seen in radial section, consists of cells that are either isodiametric or but slightly elongated longitudinally and, as noted in the cross section, arch into the cavity. These are followed laterally and at the top and bottom by other cells that are elongated in the direction of the grain and grade into typical parenchyma. The tracheids which border vessel cavities are not found near the centers of resin formation.

As in the cross section the remainder of the area is occupied by extensive tracts of libriform fibers, which are so closely crowded that the contour of the individual elements cannot be followed with any accuracy. The tissue presents a striated appearance, which owes its origin to the thick walls of the libriform cells set off by the narrow lumina alternating with them, and is easily distinguishable from the portions of the wood reserved for conduction and storage. It follows that the contour and extent of the patches of mechanical tissue must of necessity vary widely, not only in different sections but in different parts of the same section, since their orientation with regard to the other elements is purely accidental in a diffuse porous wood of this type. Laterally they are margined by parenchyma bordering resin cysts and vessels, and vertically by ray flecks. In addition the regularity is broken here and there by rows of vertical parenchyma, which formation is often changed through subsequent septation into catenate strings of idioblasts. The latter are prominent owing to the size of the crystals.

Tangential section.—(Plate 8.) The tangential section departs strikingly in appearance from the radial owing to the fact that the wood rays are now seen transversely as fusiform structures with their long axes directed longitudinally. They are typ-

ically diffuse in arrangement and vary in height from ten to sixty cells and in width from one to six cells, respectively. The cells on the upper and lower edges are larger (heterogeneous) and appear cuneiform, conforming with the contour of the ray, while those in the body vary from orbicular to ovoid or polygonal and measure from 10 to 54 μ.[24] All the cells contain organic matter, which either fills the lumina or occurs as a thin layer lining the wall. The horizontal resin ducts, described by Pfeiffer in the wood rays of three of the Javanese dipterocarps,[25] are totally wanting in *Parashorea*.[26]

Aside from the vessels, the vertical elements present the same features as in the radial section and require no further discussion here. They follow a sinuate path, owing to deflections occasioned by the larger rays, in contrast to their straight course in the radial section. In addition the individual vessel segments differ in appearance in that the terminal constriction which is perforated is now seen to be slightly oblique; where a segment is seen in median section, the points of constriction are no longer opposite each other, indicating that the vessel segments arise from fusiform initials similar to those which give rise to tracheids but have reached a high stage of development.[27]

The tangential section likewise affords the best opportunity to observe the formation of tyloses. As noted previously these arise from parenchyma which is contiguous to vessels and in *Parashorea* is traceable to wood rays, more especially the uniseriate rays. The latter are abruptly deflected where vessels intercept their course, curve around them, and subsequently form tyloses along the line of contact, which in tangential sections appear as lateral cystlike structures emanating from the rays. Whether or not tylosic formation, which owes its origin to the proximity of a vessel, results in this case from tension in the ray cells is debatable, but it seems reasonable to assume that this condition exists.

[24] The cells along the lateral margins tend to be somewhat larger than those deeper within the body of the ray.

[25] Pfeiffer, J. Ph., De Waarde van Wetenschappelijk Onderzoek voor de Vaststelling van Technische Eigenschappen van Hout. Amsterdan, J. H. de Bussy (1917).

[26] I have observed horizontal resin ducts in only one of the thirty-two species of Philippine dipterocarps that I have examined. This is *Shorea mindanensis* Foxworthy, a species restricted to Mindanao and Basilan.

[27] See Jeffrey, E. C., The Anatomy of Woody Plants. University of Chicago Press (1918).

There now remains but the discussion of the minute details of pit structure and intercellular spaces to complete the present investigation. Discussion of these has purposely been left until the last since they required magnifications ranging from one to two thousand, which were wholly unnecessary for the remainder of the study. In the foregoing pages mention has been made of the kinds of pitting that characterize prosenchyma and parenchyma, namely, the bordered and the simple type, and this point should be borne in mind in order to understand more clearly the prevailing relationships. It is assumed, moreover, that the reader is familiar with the general details of structure that characterize simple and bordered pits.

The pitting of *Parashorea* is depicted in Plate 9 and exhibits a surprising range of variation in form and size, which is in part traceable to the type of element concerned and in part to the angle of vision. Throughout, the pit cavities present a punctate appearance, owing to the presence of granular organic material which, when a pit is seen in surface view, suggests perforated pit membranes as reported by Jönsson [28] in certain Leguminosæ, an illusion which is readily corrected when the pits are seen in sectional view. Whether this organic material is in the nature of a residue left behind following the disappearance of the protoplasts in the cells concerned or is of physiological significance can only be conjectured. A second striking feature is the noticeable lack of tori in the membranes of the bordered or semibordered pits, a condition that apparently holds throughout the dipterocarp family. Even where the pits are distinctly bordered and approach those of coniferous wood, the middle lamella spanning the pit cavity presents an even appearance without suggestion of thickening of any sort. *Parashorea* wood is characterized by the total absence of tori in the pit membranes.

As seen in surface view the simple pits appear as circular, oval, or polygonal areas (Plate 9, fig. 11) delimited by a simple margin which denotes the inception of the pit cavity. The shape of the latter is variable, depending upon the proximity of other pits and the type of cells neighboring the parenchyma. In ray parenchyma the simple pits may become so numerous as to present a latticelike appearance.

[28] Jönsson, B., Siebähnliche Poren in den trachealen Xylemelementen der Phanerogamen, hauptsächlich der Leguminosen, Ber. Deutsch. Bot. Ges. 10 (1892) 494–513.

In sectional view the simple pit is seen (Plate 9, fig. 12) as a thin place in the cell wall arising through the absence of secondary layers or opposite sides of the middle lamella. The secondary layers end abruptly (without arching over) causing a break in the cell wall which is spanned only by the middle lamella. The structural details of the simple pits of *Parashorea* exhibit no departures from the usual type.

The bordered pits, on the contrary, present a wide range of variation in conformity with that of the elements on which they occur. Those that are found on vessel or tracheid walls are rounded or oval in surface view with a circular or flattened orifice. Such elements, while performing the mechanical function, are primarily concerned in water conduction and elongate but little following their origin in the lateral meristem. As a result, the pits are not stretched to any great extent. Fiber tracheids and libriform fibers, on the other hand, undergo marked changes as they mature, especially in longitudinal dimension, to fit them for their mechanical rôle. Consequently the bordered pits become very much flattened and attenuated spirally, and the pit orifice is reduced to a mere slit. The pits may become so altered in libriform fibers as to appear simple (Plate 9, fig. 9).

Plate 9 (figs. 1 to 9), presents various aspects of bordered or semibordered pits in sectional view, and the several departures deserve mention here. Pits leading from tracheid to tracheid are of the type common in coniferous and dicotyledonous wood except for the absence of tori. The pit cavity is widest at the middle lamella and tapers gradually toward the cell lumina. A curious modification, however, is to be noted in the bordered pits of vessel walls, since in these the pit flares again at either orifice giving the appearance of a double dumb-bell, a condition that is observable only in cross section; in longitudinal section such pits appear as in Plate 9, fig. 3, indicating that the constriction in the pit cavity is not annular but is limited to the sides. It follows that where vessels abut on tracheids the pit cavity is constricted on the vessel side, but of normal contour in the tracheid wall. Figures 7 to 9 of this plate are sections of pits that are very much attenuated, a type common on the walls of libriform fibers.

In conclusion, mention must be made of the intercellular spaces which are characteristic features of all woody tissue and provide a means of aëration for the cells that retain living

protoplasts as long as they are a part of the sapwood. Such spaces are seen to advantage in cross section, particularly in the libriform tissue, as minute chinks at the corners where three or more cells meet or in tangential sections where wood rays and vertical elements are coterminous. Such spaces are of undoubtedly physiological significance in the life economy of trees, but are often overlooked in a study of the wood owing to their reduced size.

COMPARATIVE ANATOMY OF THE MORE-IMPORTANT DIPTEROCARP SPECIES

In the following pages are incorporated the results of an investigation into the comparative anatomy of dipterocarp woods and their microscopic features. The Philippine species have never been subjected to a comparative microscopic study, and the present paper embodies much needed anatomical and taxonomic data. I plan to supplement this information by subsequent contributions as my knowledge of the woods of this important family increases, and desire the present work to be considered only in the nature of a preliminary survey.

GROSS FEATURES OF DIPTEROCARP WOODS

To one whose studies have been confined to the timbers of the Temperate Zone, the most striking feature of dipterocarp wood is the absence of distinct growth rings. The annual zones so characteristic of extratropical woods are wanting, owing to the fact that dipterocarps are evergreen trees of the tropical rain forests and growth is practically continuous throughout the year. Their wood when viewed in transverse section at low magnification is seen to consist of tracheids and parenchyma, traceable to fluctuating growth intensity. The faint lines delimiting the growth rings of the diffuse porous woods of the temperate regions are wholly wanting; the wood is characteristically diffuse, but diffuse in the sense of being homogeneous.

The woods of this family are further characterized by the presence of resin cysts, a feature which is diagnostic for the group. These consist in a series of tabular cavities which extend vertically for long distances in the tree, possibly from the roots continuously to the leaves, and appear in the majority of cases as white lines, owing to the nature of their contents.

In transverse section at low magnifications they generally occur as white dots[29] arranged in uniseriate rows which extend tangentially—that is, at right angles to the wood rays—but in certain species of *Vatica*, *Anisoptera*, and *Dipterocarpus* the arrangement may become more or less diffuse through the interruption of the lines. The radial distribution of the rows is very variable. They occasionally become practically coterminous and a biseriate or multiseriate condition may result, while in other trees, several centimeters may intervene between neighboring series. In general, suppressed or slower-growing trees exhibit the larger number, a condition which may be traceable to restricted growth or resulting traumation.[30]

Dipterocarps, in common with other trees of the tropical and temperate regions, exhibit interlocked grain, which is occasioned through a change in the direction of the vertical elements at different points along the radii of the log and results in zones in which the fiber direction alternates. Whether these are correlated in any way with annual thickening or fluctuating growth intensity is open to conjecture, but it is known that each represents the increment accruing from several seasons. Sawyers take advantage of this alternating grain in the conversion of the timber and quarter-saw logs, not only to obtain a "ribbon grain" which enhances the figure and value of the wood, but also to obtain boards which exhibit the minimum amount of warping.

As is to be expected in a family of such wide distribution in the Oriental Region and diversified habitat, dipterocarp woods display much variation in such physical properties as color, texture, and hardness, and lend themselves to multiferous uses. A brief enumeration of some of the more-striking

[29] The resins contained in the ducts are in the liquid or semiliquid state before the trees are felled but harden into a whitish mass upon drying. In some species of *Shorea* (*S. palosapis* and *S. eximia*) the resins volatilize, leaving the ducts quite empty; in others, like *Dipterocarpus grandiflorus* they are viscous, slow-drying oils. Clover, Philip. Journ. Sci. 1 (1906) 191, states that this viscous substance contains solid resin, water, and from 25 to 40 per cent of volatile oil, and believes it is a sesquiterpene or a mixture of this class of substances.

[30] In addition horizontal resin cysts are present in a few species, but they are exceedingly minute and can only be seen at higher magnification; however, Pfeiffer, loc. cit., states that some of the Javanese species exhibit resin ducts that are visible to the naked eye.

features may not be out of place here as indicative of the extremes which may be expected.

The color ranges from light yellow which is found in all species of *Anisoptera*, and in *Hopea acuminata* Merrill, *H. pierrei* Hance, *H. philippinensis* Dyer, *Isoptera borneensis* Scheffler, and *Shorea balangeran* (Korthals) Dyer, to dark reddish brown as in *Hopea plagata* Vidal. Shades of red predominate in all species of *Dipterocarpus*, *Shorea polysperma* Merrill, *S. negrosensis* Foxworthy, *S. palosapis* (Blanco) Merrill, *S. teysmanniana* Dyer, and *S. guiso* (Blanco) Blume. Certain forms, such as *Balanocarpus cagayanensis* Foxworthy and *Hopea mindanensis* Foxworthy, posses wood which, when green or freshly exposed, exhibits a greenish cast or grass green streaks, the color changing to dark brown with age (oxidation) and exposure to light.

Dipterocarp wood is coarse textured as a rule, a condition which is occasioned more by the large size of the vessels than by increased dimensions of the remaining elements. In fact, the coarsest commercial timbers of the Islands belong in this family, and only a few species of the family, such as *Vatica mangachapoi* Blanco and forms of *Hopea* and *Balanocarpus*, exhibit fine texture.

Finally, a surprising range of weight, hardness, strength, and durability is to be noted in the group, which may be illustrated by reference to woods representing the two extremes. *Shorea palosapis* (Blanco) Merrill is soft and light (specific gravity, 0.340)[31] and is not, in a strict sense, a structural timber. The opposite extreme is represented by such a wood as *Hopea plagata* (specific gravity, 1.202), which is very hard and very heavy and makes an excellent structural timber. Between these extremes all variations in weight, hardness, and strength occur. Durability in contact with the soil is in general directly proportional to weight, a condition which does not always hold for woods of the temperate regions nor for those of many tropical families. The softer, lighter dipterocarps of the genera *Anisoptera, Dipterocarpus, Shorea, Pentacme*, and *Parashorea* are not durable in contact with the ground, while the harder, heavier forms, such as *Isoptera borneensis, Shorea balangeran*, and *Vatica* species, are noted for their lasting qualities.

[31] Specific gravity determinations were made on mature woods (heartwood) with moisture content varying from 6 to 8 per cent.

MICROSCOPIC FEATURES OF DIPTEROCARP WOODS

The elements which make up dipterocarp wood, aside from the fiber tracheids,[32] have been enumerated and discussed in detail in this paper, and there remains but to point out the variations as to size, number, and alignment as found in the various genera and species. Dipterocarp woods, as is the case in those of other families, exhibit many microscopic features in common; and the anatomical differences that separate genera and species and which have such an important bearing on the physical properties of the wood are traceable to fluctuations in size, number, and arrangement, rather than to kinds of elements.

The most obvious evidence of modifications in the anatomy of the various dipterocarp woods is varying texture. The latter is governed by the size of the vessels in the main, since the fibrous elements in strictly diffuse porous woods of the dipterocarp type are too small to have their fluctuations in dimensions count for much in terms of texture. In discussing the vessels of dipterocarps it has seemed advisable to adopt an arbitrary classification governed largely by the magnitude of variation in the diameter of the average pore, and the following groups were finally evolved as the study developed.

Vessels	μ
Very small	50–100
Small	100–150
Medium	150–200
Large	200–250
Very large	250–400

Vatica mangachapoi and *Hopea plagata* are representative of the lower extreme and possess pores that average less than 100 μ in diameter. They are accordingly to be considered as very fine textured and in addition are hard and heavy as well. *Shorea negrosensis* and *Shorea eximia* typify the other extreme and possess pores that average over 250 μ in diameter; they are among the coarsest of the Philippine dipterocarps. Between these two extremes all gradations occur, a feature which is responsible, at least in part, for the wide utility of the woods of this family.

[32] Fiber tracheids, as the term implies, are intermediate in type between tracheids and libriform fibers and are wholly wanting in *Parashorea* wood. They are longer than tracheids but still retain the bordered pit which, however, is reduced in size and often somewhat attenuated.

While dipterocarp woods are diffuse, and diffuse in the sense of being homogeneous in that the annual zones of extra-tropical woods are lacking, they nevertheless exhibit minor variations in pore alignment. For example, the vessels of *Anisoptera, Dipterocarpus,* and *Vatica* are predominately solitary and show little tendency toward grouping, while the majority of the members of this family are characterized by groups of three or more (as high as fifteen in certain species) which are contiguous in short rows, or string out obliquely to the wood rays, a condition that is typified by *Parashorea.*

Tylosic ingrowths are always present and arise in the same manner as do those of temperate-region woods; namely, from pits leading to parenchyma proximate to the vessels. They vary in prominence and are most copiously developed in the harder and heavier species where they often completely occlude the pores. *Shorea balangeran, Isoptera borneensis, Hopea plagata,* and *Vatica* are striking examples. On the other hand tyloses are usually sparsely developed in the softer, lighter species of the genera *Shorea, Pentacme, Parashorea, Dipterocarpus,* and *Anisoptera,* the woods of which are among the most perishable of the dipterocarps.[33]

The structure of the individual tyloses varies somewhat in the different species and deserves mention here. In the majority of cases it takes the form of a thin-walled, more or less globose cyst, which at low magnifications is somewhat iridescent. Where several such cysts originate about the wall of the vessel at nearly the same height crowding ensues, resulting in forms of irregular shape, and the vessel becomes solidly packed at that point. As a rule the wall of the tylosis is thin and cellulosic in character but may, in some species, as *Vatica mangachapoi* Blanco, become more or less thickened, lignified, and provided with simple pits. As has been pointed out by other workers, the presence of tyloses is indicative of increased durability, since they inhibit the movement of air and moisture in the wood, thus restricting fungal growth.[34]

[33] In species of *Dipterocarpus* although tyloses frequently occur in the pores they do not completely block the passage of air and liquids, as may be seen by blowing smoke through a section of wood. This fact is undoubtedly responsible for the facility with which wood of *Dipterocarpus* species takes preservative treatment.

[34] This is true of the majority of dipterocarps, but it does not seem to hold good in the case of *Pentacme contorta* and *Dipterocarpus grandiflorus. Pentacme* has a more highly developed tylosis, but *Dipterocarpus* is the more durable of the two.

Tracheids are present in the majority of the dipterocarp woods and exhibit the same appearance and disposition as in *Parashorea*. They vary in number from several to a dozen or more and are always confined to the immediate vicinity of the vessels where, in conjunction with the vasicentric parenchyma, they form areas of lighter tissue about the pores.

Among the species examined tracheids are most numerous in *Parashorea malaanonan* and *Isoptera borneensis*, where as many as thirty are sometimes present in a group. The opposite extreme is found in *Vatica*, *Balanocarpus*, and species of *Hopea*, in which tracheids are conspicuous by their absence. The same applies to *Anisoptera* and *Dipterocarpus*, but in these genera the tracheids are replaced by an intermediate type of element, the fiber tracheid (see footnote 32). The transition from tracheids to libriform fibers is always abrupt, since vertical parenchyma usually intervenes; fiber tracheids, on the contrary, usually grade into libriform fibers gradually.

The libriform fibers make up the background of the wood; they represent the ultimate development of mechanical tissue and consist of thick-walled, long-attenuate cells (sixty to eighty times as long as wide) which occur en masse and take very little, if any, part in the movement of solutes in the tree. Extremes of variation are found in *Hopea plagata* (15 by 1,300 μ), *Vatica* (18 by 1,340 μ), and *Balanocarpus* (18 by 1,380 μ), which represent the minimum, in contrast to *Dipterocarpus verniciflfuus* (27 by 1,790 μ), *Shorea teysmanniana* (31 by 1,370 μ), and other species of *Shorea*, *Pentacme*, and *Parashorea*. In addition a curious relation was found to exist between fibers and pores; in small-pored woods the fibers were invariably of more-restricted dimensions than in woods of coarser texture.

Libriform fibers fluctuate not only in dimensions-over-all in the various species, but likewise in the thickness of the cell wall. It follows obviously that the latter varies in inverse ratio to the thickness of the cell lumen and that the density of the wood is directly proportional. The relatively light and soft species of *Shorea*, *Pentacme*, and *Parashorea* are characterized by thin-walled libriform tissue, while the reverse applies in such hard and heavy species as *Shorea balangeran*, *Hopea plagata*, and *Vatica mangachapoi*.

The vertical parenchyma of dipterocarp wood is variable in the different genera and species, both in amount and in distribution. Two types are prevailingly present in all members of the family, the vasicentric and the diffuse. The former,

as the term implies, is associated with the vessels which it may bound directly but from which it is usually separated by intervening tracheids or fiber tracheids. The vasicentric parenchyma may be restricted in amount to only a few cells, but often exhibits a tendency toward extension tangentially, suggesting eyelets, or even crosses one or more wood rays. This is especially true of most species of *Shorea* and *Hopea* and of *Balanocarpus cagayanensis.*

The diffuse type may be represented by isolated cells that border wood rays or are embedded in the midst of the libriform tissue, as in *Anisoptera* and *Dipterocarpus*, but the arrangement is generally diffuse-zonate, in lines one (*Hopea plagata*) or more (*Isoptera borneensis, Hopea mindanensis*) cells in thickness which connect the wood rays and in which the resin cysts are embedded. In fact, all gradations, from the vasicentric through the vasicentric-zonate and diffuse-zonate to the strictly diffuse type, are to be found. Vertical parenchyma is always present though seldom conspicuous in the wood of the various species.

The horizontal parenchyma of dipterocarp wood is confined to the wood rays which vary appreciably in size and abundance, not only in the wood of the different species of dipterocarps but in different samples of the same species. *Dipterocarpus, Anisoptera,* and numerous species of *Shorea, Pentacme,* and *Parashorea* are characterized by large rays (sometimes one hundred cells high by nine cells wide) which make up from 14 to 18 per cent of the volume of the wood. The other extreme is represented by the finer-textured species of *Hopea* and *Balanocarpus* where normally the rays do not exceed sixty cells in height and five in width with which a reduced ray volume may or may not be correlated. All gradations between these extremes occur, but in general the finer-textured woods are characterized by smaller rays.

The individual rays are, without exception, of the heterogeneous type with distinct marginal cells which show to best advantage in radial section. Occasional rows of similar cells are not infrequent in the body of the ray where two distinct types of arrangement are to be noted. In the majority of cases they are interpolated among the rows of normal cells throughout the body of the ray, irrespective of the margin, and present no unusual features. In *Dipterocarpus* and *Anisoptera,* to the contrary, such interspersed rows are confined to the lateral

margins of rays and appear in tangential section as large cells bounding a central core of smaller elements. The significance of the latter arrangement has not as yet been determined.

As is often the case in other tropical families, dipterocarp woods are characterized by the presence of more or less extraneous organic matter which takes the form of amorphous brown infiltrations in the lumina of the parenchyma cells. Such organic products are usually confined to the ray cells and, as seen microscopically, appear as gummy incrustations lining the walls or filling the lumina entirely and then rendering the details of pit structure obscure. Rarely is the vertical parenchyma involved, and only when the ray cells are thoroughly impregnated is there an apparent leakage into the vertical cells. Such organic infiltrations may be reserve food which was not utilized in the further growth of the tree or, on the other hand, may be by-products of metabolism which have been deposited in the ray cells. These infiltrations are very distinct in the red lauaans such as *Shorea negrosensis* and *Shorea polysperma;* in fact, these woods in part owe their color to them. The paler white lauaans, on the contrary (*Shorea mindanensis, Pentacme contorta,* and *Anisoptera* spp.), are characterized by meager organic infiltration.

Idioblasts are present in the majority of dipterocarp woods and, as previously pointed out, have their origin in parenchyma, in both the vertical and the horizontal wood rays. Such cells usually become further segmented by secondary septa into a number of compartments in each of which a tetragonal crystal of calcium oxalate is formed. Where the rows of vertical parenchyma are involved, catenate strings result which stand out in section against the remaining tissue; on the other hand, it is not uncommon to find all the cells of a wood ray modified into idioblasts.

Idioblasts are of some diagnostic value owing to their varying distribution in the different species, a feature that has been employed to advantage in the following keys. For example, both kinds are present in *Parashorea malaanonan, Hopea acuminata, H. mindanensis,* and in species of *Pentacme.* In contrast to the above, vertical idioblasts are wanting in *Vatica mangachapoi, Hopea plagata,* and a few other forms, which is also true of the horizontal idioblasts in *Isoptera borneensis, Shorea balangeran,* and *S. guiso.* Further study and examination of many samples of each species are necessary, however, to verify the value of

idioblasts in identification, as their presence and abundance are undoubtedly influenced by various factors, such as soil chemistry and root absorption.

Mention has already been made of the gross features and distribution of the resin cysts in the dipterocarp group. They arise schizogenously through the fission of parenchyma cells and are borne in series which simulate the resin canals of the conifers. In the majority of the Philippine dipterocarps the series are restricted to a vertical alignment, and the various rows of cysts are arranged in interrupted lines which extend tangentially; but in certain species the solitary arrangement prevails, either wholly (*Vatica*) or in part (*Dipterocarpus* and *Anisoptera* spp.). Horizontal resin cysts are very rarely present, having been observed in but one (*Shorea mindanensis*) of the twenty-four species examined.[35] They are confined to the wood rays and, as seen in tangential section, appear as small apertures encircled by minute epithelial cells which are in turn bordered by normal ray cells. In contrast to the conifers where normally but one duct is found in a given ray which is thereby altered in contour (fusiform), the rays of *Shorea mindanensis* sometimes include two series of cysts but the ray remains unchanged in form. The evolutionary significance of the absence of horizontal resin cysts in the Philippine dipterocarps, aside from *Shorea mindanensis*, remains to be determined.

As seen transversely, resin cysts vary little in shape and size in the various species and little diagnostic value can be attached to such variation. Isolated cavities are usually rounded, while those of the tangential rows are compressed tangentially. Size manifests itself only in relative conspicuousness and is of little value, owing to the irregular distribution of cysts. *Vatica* is characterized by small resin cavities, while the other extreme is represented by *Dipterocarpus*.

In the following pages I have handled the subject somewhat differently from other investigators in that I have made the keys to lead to well-established commercial groups rather than to natural genera, for the sole reason of making the keys conform with the classification in the trade as well as in the forestry regulations in as much as government charges on such timbers are based on these groups.

[35] Pfeiffer (footnote 25) reports horizontal resin ducts in various Javanese dipterocarps. I have also observed them in samples from Borneo and Federated Malay States.

Key to well-established commercial groups of Philippine dipterocarp woods.

1. Resin cysts diffuse, not connected by parenchyma, occurring scattered; pores often filled with whitish resin.. 2.
   Resin cysts in concentric rings, more or less connected by light bands of parenchyma; pores very seldom if ever filled with resin............... 4.
2. Wood coarse textured; vessel lumina open, visible to the naked eye; specific gravity generally not over 0.80.. 3.
   Wood very fine textured; vessel lumina very small, not visible to the naked eye; specific gravity over 0.85.............................. **Narig group.**
3. Wood pale white to yellowish, occasionally with pinkish or reddish tinge .... **Palosapis group.**
   Wood reddish to reddish brown, often with distinct odor of resin. **Apitong group.**
4. Wood coarse textured, soft to moderately hard, light to moderately heavy; specific gravity generally not over 0.60............ **Lauaan group.**
   Wood medium to fine textured; hard to very hard, heavy to very heavy, specific gravity generally over 0.70.. 5.
5. Wood reddish brown or with vinaceous tinge, evenly colored. **Giho (*Shorea guiso*).**
   Wood yellowish, yellowish green, or golden brown, rarely reddish with greenish concentric bands.. 6.
6. Wood yellowish, turning to golden yellow with age, fine textured; hard and heavy; specific gravity generally below 0.80.... **Manggachapui group.**
   Wood yellowish brown or occasionally reddish with a greenish tinge, variable in texture; hard to very hard, heavy to very heavy; specific gravity over 0.85.. **Yakál group.**

THE NARIG GROUP

The narig group is the product of the genus *Vatica* which is represented in the Islands by five described species. The woods of this genus are very much alike and differ only in their minute features.

Gross features.—Sapwood light yellowish, thick, very resinous, exuding resin until thoroughly seasoned; heartwood light yellow when first exposed, turning to reddish yellow with age. Wood very fine textured and fairly straight grained, very hard, and very heavy; specific gravity, about 1.

Microscopic features.—Vessels very small (20 to 150 μ in diameter), completely occluded with tyloses; tyloses with simple pits. Tracheids and fiber tracheids absent. Libriform fibers with distinct radial arrangement, often polygonal in transverse section. Vertical parenchyma scanty, vasicentric and diffuse, easily mistaken for pores. Idioblasts present.

Remarks.—The woods of this group are seldom found in the trade, owing to their scarcity, although *Vatica* species are widely distributed throughout the Archipelago. Only one species, *Vatica mangachapoi* Blanco, is of importance.

VATICA MANGACHAPOI Blanco. NARIG. (Plate 10.)

Gross features.—Sapwood light yellowish, thick; heartwood yellowish when first exposed, turning to russet with age. Wood the finest textured of any of the dipterocarps, fairly straight grained, very hard and very heavy; specific gravity, 0.878 to 1.03.

Microscopic features.—Vessels numerous, rounded in transverse section, from 23 to 150 μ (average, 80) in diameter; tyloses numerous, sclerosed, with simple pits. Tracheids and fiber tracheids wanting. Libriform fibers radially arranged, 18 by 1,340 μ, rounded in transverse section, lumina small; wall approximately 7.5 μ thick. Vertical parenchyma vasicentric and diffuse; gummy infiltration products globular. Resin cysts diffuse, one-third to one-half the size of the pores. Idioblasts strictly horizontal,[36] very conspicuous. Wood rays straight, broad, 4 or 5 by 55 cells in transverse section, ray parenchyma filled with gummy, globular infiltrations.

Remarks.—*Vatica mangachapoi* is widely distributed throughout the Archipelago and is found from the Babuyan Islands southward to Basilan. The heartwood in contrast to the perishable sapwood is extremely durable and is largely employed for railroad ties and other purposes where strength and durability are required. This species is sometimes mistaken for the fine-textured yakáls but can easily be separated from the latter by (*a*) the diffuse character and small diameter of the pores and resin ducts, (*b*) the absence of zonate concentric parenchyma, and (*c*) by the comparatively large sapwood.

THE APITONG GROUP

The apitong group is represented in the Philippines by seventeen species, all of which are products of the genus *Dipterocarpus* and constitute about 17 per cent of the total volume of the Islands' forest resources. The woods are very similar in their gross features and are not distinguished in the market. Among the most-important species are *D. grandiflorus*, *D. pilosus*, and *D. vernicifluus*.

Gross features.—Sapwood grayish red when fresh, medium thick; heartwood reddish, turning to reddish brown with age. Wood hard, heavy; specific gravity, 0.587, Gardner, 0.879; resinous, straight grained. Resin cysts prominent, diffuse.

[36] Ray idioblasts are designated as horizontal to distinguish them from the idioblasts arising from the vertical parenchyma.

Microscopic features.—Vessels large (228 to 273 μ in diameter), occasionally occluded with tyloses. Tracheids wanting, as in *Anisoptera.* Fiber tracheids prominent, proximate to the vessels. Libriform fibers more regularly arranged radially than in *Anisoptera,* averaging 26 by 1,700 μ in size. Vertical parenchyma vasicentric and diffuse. Resin cysts, diffuse; epithelial cells flattened. Idioblasts absent. Wood rays 3 to 5 by 40 to 50 cells in transverse section.

Remarks.—The woods of the three species of *Dipterocarpus* are so similar in their gross and minute anatomy that it seems undesirable to attempt to separate them in a key.

DIPTEROCARPUS GRANDIFLORUS Blanco. APITONG. (Plate 11.)

Gross features.—See Gross Features of the apitong group.

Microscopic features.—Vessels large, 162 to 324 μ (average, 263) in diameter, numerous, rounded ovoid or oblong in transverse section, solitary or in groups of 2 to 6; tyloses relatively few, distinct. Tracheids wanting. Fiber tracheids prominent, proximate to the pores. Libriform fibers numerous, 26 by 1,690 μ. Vertical parenchyma vasicentric and diffuse, the latter in tangential strings of 2 to 7 cells, not as prominent as in *D. verniciflnus.* Resin cysts diffuse or occasionally in groups of 2 to 4 and then in interrupted concentric rows, rounded in transverse section, epithelial cells flattened. Idioblasts wanting. Wood rays 3 by 40 cells in transverse section.

Remarks.—Used for ordinary construction and medium-grade furniture. Not durable when exposed but lasting an indefinite period when protected from moisture. In the temperate regions where termites (white ants) and fungi are less destructive, apitong will make desirable wood for railroad ties and structural timbers where a strong hardwood is required. Like other members of the genus, apitong is easily impregnated with preservatives. The wood of this species is occasionally substituted for giho, a higher grade of timber. *Dipterocarpus grandiflorus* is widely distributed in the islands from Cagayan southward to Agusan and is one of the most abundant of the dipterocarps.

DIPTEROCARPUS VERNICIFLUUS Blanco. PANAU. (Plate 12.)

Gross features.—The wood is very similar to apitong in general appearance but is of somewhat coarser texture; specific gravity, 0.699.

Microscopic features.—Vessels large, 73 to 384 μ (average, 273) in diameter, ovoid or oblong in transverse section, the

latter type predominating; tyloses rare, inconspicuous. Tracheids and fiber tracheids as in *D. grandiflorus*. Libriform fibers numerous, radially arranged; walls average 8.8 μ in thickness. Vertical parenchyma vasicentric and diffuse. Resin cysts diffuse, surrounded by several layers of vertical parenchyma. Idioblasts wanting. Wood rays 5 by 50 cells in transverse section; ray cells with infiltrations which are not so prominent as those of *Parashorea*.

Remarks.—Used for the same purposes as apitong. This species is very widely distributed in the Islands from northern Luzon southward to Basilan. It is frequently tapped for resin which is used for calking ships.

DIPTEROCARPUS LASIOPODUS Perkins. HAGAKHAK. (Plate 13.)

Gross features.—The wood, like that of *D. vernicifluus*, is scarcely to be distinguished from apitong in general appearance; specific gravity, 0.699.

Microscopic features.—Vessels large, 88 to 294 μ (average, 228) in diameter; generally more variable and of smaller average size than the two preceding species. Tracheids wanting. Fiber tracheids common, proximate to the vessels. Libriform fibers numerous, 26 by 1,620 μ, zonate and compressed at intervals, indicative of restricted growth. Vertical parenchyma and resin cysts as in *Dipterocarpus grandiflorus*. Idioblasts wanting. Wood rays 4 by 50 cells in transverse section, usually with infiltration products.

Remarks.—Used for the same purposes as apitong. Like apitong and panau, hagakhak is found in virgin forests associated with other dipterocarps. Reported from northern Luzon southward to Zamboanga and Basilan, and said to be especially abundant in Mindoro.

THE PALOSÁPIS GROUP

The palosapis group comprises the five species of *Anisoptera* that are found in the Islands. The woods are practically alike in their general features and cannot be separated on superficial examination. Since this genus does not produce wood belonging to other groups, the following description applies to the genus itself.

Gross features.—Sapwood pale white, turning to gray or brown, medium thick; heartwood pale white to yellowish when freshly cut, occasionally with pink or rose red streaks, turning pale yellow with age. Texture coarse. Pores large, conspicu-

ous, visible to the naked eye. Resin cysts diffuse or rarely in interrupted concentric rings. Grain straight or rarely crossed. Wood medium hard and medium heavy; specific gravity, 0.399, Gardner, 0.857.

Microscopic features.—Vessels large, 158 to 250 μ in diameter; tyloses inconspicuous. Tracheids absent. Fiber tracheids present as in *Dipterocarpus*. Libriform fibers without distinct radial arrangement, 22 to 28 by 1,270 to 1,930 μ. Vertical parenchyma vasicentric and diffuse, the latter very prominent. Resin cysts diffuse-rounded. Organic infiltration scarce. Idioblasts wanting.

Remarks.—Two species, *A. thurifera* and *A. curtisii*, are commonly found in the markets, both reaching large size.

Key to the common commercial species of Anisoptera.

1. Pores over 200 μ in diameter; libriform fibers slender and long, 22 by 1,600 μ; wood rays large, 6 by 100 cells. Palosapis (*Anisoptera thurifera*).
   Pores under 200 μ in diameter; libriform fibers stout and short, 26 by 1,270 μ; wood rays smaller, 5 by 37 cells.. Dagang (*Anisoptera curtisii*).

ANISOPTERA THURIFERA (Blanco) Blume. PALOSAPIS. (Plate 14.)

Gross features.—For color of the wood see group characteristics. When freshly cut the heartwood often shows rose green which color fades out after a few hours' exposure to the air. Wood coarse textured, fairly straight grained, moderately hard to hard, moderately heavy to heavy; specific gravity, 0.793.

Microscopic features.—Vessels large, 54 to 265 μ (average, 210) in diameter, rounded or ovoid in transverse section, diffuse; tyloses scarce. Tracheids wanting. Fiber tracheids fewer than in *Dipterocarpus*, not sharply differentiated from libriform fibers. Libriform fibers numerous, 22 by 1,600 μ, with walls 8.5 μ in thickness. Vertical parenchyma vasicentric and diffuse. Resin cysts rounded on transverse section, diffuse; epithelial cells flattened. Idioblasts wanting. Wood rays heterogeneous, attaining a maximum size of 6 by 100 cells in transverse section; organic infiltration inconspicuous.

Remarks.—Used for temporary construction and cheap furniture, but not durable in contact with the soil. The wood of this species is frequently substituted for manggachapuí (*Hopea acuminata*), a higher grade of timber, but can be distinguished from the latter by its coarser texture and larger pores which are plainly visible to the naked eye. In addition, the resin cysts of manggachapuí are arranged in concentric rings.

ANISOPTERA CURTISII Dyer. DAGANG. (Plate 15.)

Gross features.—For color of the wood see group characteristics. The wood is very similar to that of *A. thurifera* in general appearance, but is of somewhat finer texture; specific gravity, 0.707.

Microccopic features.—Vessels medium large to large, 40 to 235 μ (average, 158) in diameter, rounded or ovoid in transverse section, diffuse. Tracheids wanting. Fiber tracheids as in *A. thurifera*. Libriform fibers numerous, 26 by 1,270 μ with walls 8 μ in thickness, irregular in arrangement; stone cells with bordered pits occasionally present. Vertical parenchyma less conspicuous than in *A. thurifera*. Resin cysts rounded in transverse section, diffuse. Idioblasts wanting. Wood rays heterogeneous, smaller than in *A. thurifera*, 5 by 37 cells in transverse section.

Remarks.—Used for the same purposes as palosapis where cheapness is the prime factor rather than strength and durability. Dagang is of more-restricted distribution than *A. thurifera*, but has been reported in Luzon from Pangasinan, Nueva Ecija, Laguna, Tayabas, and Camarines, and in Negros and Polillo.

THE LAUAAN GROUP

The lauaan group is the product of the genera *Pentacme*, *Parashorea*, and *Shorea*, the woods of which are the most important source of cheap structural timber in the Islands, and constitute the real forest wealth of the Philippines. They are among the largest of the dipterocarps, attaining a height of 60 meters and a diameter of 2 meters, and supplant the pines and other conifers in the local markets. As a group, lauaans are the least durable of the dipterocarps.

Gross features.—Sapwood grayish white, medium wide, subject to blue stain; heartwood varying from pale yellow to dark red. Texture coarse to very coarse. Pores medium to very large. Resin cysts in interrupted concentric lines, or both zonate and diffuse. Grain commonly crossed. Wood soft to medium hard, light to moderately heavy; specific gravity, 0.340 to 0.720.

Microscopic features.—Vessels medium to very large, 194 to 329 μ in diameter, tyloses inconspicuous. Tracheids few, confined to the immediate vicinity of the vessels. Fiber tracheids absent or at most inconspicuous. Libriform fibers with more or less regular radial arrangement, 22 to 28 by 1,360 to 2,020 μ,

generally flattened tangentially, with wide lumina. Vertical parenchyma vasicentric, zonate or diffuse. Resin cysts compressed, inconspicuous as compared to the vessels. Idioblasts present or absent. Wood rays 3 to 9 by 35 to 90 cells in transverse section.

Remarks.—The lauaan group may be divided into two subgroups; namely, the red lauaans and the white lauaans, which are separated as follows:

1. Wood reddish brown to brick red .... **Red lauaans.**
   Wood pale yellow to light red or pinkish .... **White lauaans.**

SUBGROUP RED LAUAANS

The red lauaans are wholly confined to the genus *Shorea* [37] and are characterized by the reddish brown or brick red color of the wood. The following key is based on the gross and minute characteristics of the wood and should assist in the separation of species.

Key to the commercial species of red lauaans.

1. Wood light red; resin cysts small, inconspicuous, empty, that is, without whitish deposits .... **Mayapis** (*Shorea palosapis*).
   Wood red to dark red; resin cysts conspicuous, filled with a whitish resin .... 2.
2. Wood soft and light, specific gravity usually less than 0.5; libriform fibers over 30 μ in transverse diameter; organic infiltration in ray parenchyma uneven and generally thin.
   Tiaong (*Shorea teysmanniana*).
   Wood medium hard and medium heavy; specific gravity over 0.5; libriform fibers less than 30 μ in transverse diameter; organic infiltration in ray parenchyma copious, generally indurated .... 3.
3. Vessels very large, averaging over 300 μ in transverse diameter; tracheids three or four near the junctions of vessels; libriform fibers averaging 28 by 2,020 μ; specific gravity, 0.542.
   Red lauaan (*Shorea negrosensis*).
   Vessels medium, averaging less than 250 μ in transverse section; tracheids absent or at most one or two proximate to vessels; libriform fibers averaging 25 by 1,470 μ; specific gravity, 0.575.
   Tangile (*Shorea polysperma*).

SHOREA PALOSAPIS (Blanco) Merrill. MAYAPIS. (Plate 16.)

Gross features.—Sapwood light red, medium thick; heartwood darker, the color deepening with age. Wood coarse textured, generally cross grained, soft and light; specific gravity,

[37] The reverse does not apply. Various species of *Shorea* are included among the "white lauaans."

0.340 to 0.560 (average, 0.432). Resin cysts empty in contrast to the other lauaans.

Microscopic features.—Vessels large, 117 to 367 μ (average, 257) in diameter, rounded ovoid or oblong in transverse section, diffuse; tyloses relatively abundant, thin, unlignified. Tracheids very few, proximate to the vessels. Fiber tracheids wanting. Libriform fibers numerous, 26 by 1,540 μ, with walls averaging 2.93 μ in thickness, slightly depressed on the tangential side, arranged in regular radial rows. Vertical parenchyma vasicentric-zonate and diffuse, abundant about the resin cyst, with scanty infiltration. Resin cysts in interrupted concentric rings as in *Parashorea.* Horizontal and vertical idioblasts wanting. Wood rays narrow, 4 by 60 cells in transverse section, heavily impregnated with gummy infiltration but to a less extent than in *S. polysperma* and *S. negrosensis.*

Remarks.—Mayapis is not sold at present under its own name but generally as tangile or mixed with the white lauaans. It is used for house construction and medium-grade furniture, but requires protection from moisture, as it is one of the less durable of the dipterocarps. The species is widely distributed from Cagayan southward to Zamboanga, and the trees form heavy stands in some localities, as in Laguna Province and certain parts of Mindanao.

Mayapis is often mistaken for almon (*Shorea eximia*) but can be distinguished from the latter in that the resin cysts are free of resinous contents in contrast to those of *S. eximia.*

SHOREA TEYSMANNIANA Dyer. TIAONG. (Plate 17.)

Gross features.—Sapwood light red, distinct from the heartwood, rather thin; heartwood darker red than that of mayapis. Wood coarse textured, fairly straight grained, soft and homogeneous, light; specific gravity, 0.466, easily worked.

Microscopic features.—Vessels large, average 0.268 μ in diameter, rounded in transverse section, grouped or solitary; tyloses fairly common. Tracheids few, confined to the proximity of the vessels. Fiber tracheids wanting. Libriform fibers numerous, large, 31 by 1,730 μ, with walls that average 2.93 μ in thickness, arranged in regular radial rows. Vertical parenchyma vasicentric-zonate, occasionally solitary and diffuse; organic infiltration variable; in the harder grades, such as those coming from Sibuyan, the deposits are as thick as in *Shorea polysperma* but much restricted and often not conspicuous in the lighter grades. Resin cysts concentric as in *S. palosapis.*

Idioblasts wanting. Wood rays 3 or 4 by 50 cells in transverse section.

Remarks.—Tiaong is probably the softest and most homogeneous of the lauaans. The wood is not well known at present, but occasional lots reach the market from Sibuyan and are sold as genuine tangile or a high-grade red lauaan. It is not durable when exposed and should be used only for interior work where it will last for an indefinite time. This species is widely distributed in Luzon but has been reported from only one place in Mindanao (Agusan).

The wood of tiaong is very similar to mayapis in general appearance but differs in that the resin cysts contain white amorphous deposits. It can be distinguished from tangile because it is lighter and softer and has smaller and fewer resin cysts.

SHOREA NEGROSENSIS Foxworthy. RED LAUAAN. (Plate 18.)

Gross features.—Sapwood as in *Shorea teysmanniana;* heartwood red, turning to brick red, the darkest of the lauaans. Wood coarse to very coarse textured, cross grained, soft to moderately hard, light to moderately heavy; specific gravity, 0.541. Red lauaan resembles the wood of *Parashorea* but is coarser textured and more homogeneous as a rule.

Microscopic features.—Vessels very large, 176 to 426 μ (average, 329) in diameter, oblong or rarely rounded in transverse section, grouped or solitary; tyloses sparse as in *Parashorea.* Tracheids three or four near the junctions of vessels, larger than the adjoining wood parenchyma cells. Fiber tracheids wanting. Libriform fibers numerous, large, 28 by 2,020 μ, with wide lumina and walls 2.20 to 4.38 μ in thickness, depending on the density of the specimen, in regular radial series, simulating the tracheid arrangement in coniferous wood. Vertical parenchyma vasicentric and diffuse, similar to *Parashorea.* Resin cysts in interrupted concentric lines. Idioblasts wanting or sparse (none found in sections studied). Wood rays 3 or 4 by 50 cells in transverse section, heavily impregnated with gummy infiltration products.

Remarks.—Used for medium and high-grade furniture, house construction, and cabinet work. High-grade flitches are often converted into veneer and utilized in the manufacture of piano and phonograph cases. Not durable when exposed but lasts well when protected from moisture. Red lauaan closely resembles tangile and is often substituted for this wood in the market.

Typical specimens can be separated, owing to the coarser texture of the red lauaan as compared to tangile, but intergradations often occur which make identification difficult. In addition to the differences enumerated in the key (page 325), red lauaan is more susceptible to the ravages of ambrosia beetles; in fact, to such an extent that it is difficult to find a board that is free from "pinholes." Red lauaan is one of the species marketed under the trade name of "Philippine mahogany."

Shorea negrosensis is widely distributed from northern Luzon southward to Agusan and is especially abundant in Negros, where it forms heavy stands in association with *S. polysperma*, *S. eximia*, *Pentacme contorta*, and *Parashorea malaanonan*. Foxworthy states that this species is probably the most abundant of Philippine commercial timbers.[38]

SHOREA POLYSPERMA (Blanco) Merrill. TANGILE. (Plates 19 and 20.)

Gross features.—Sapwood light red, similar to red lauaan and tiaong; heartwood generally lighter[39] than red lauaan, the harder grades occasionally with a dark purplish tinge. Wood medium to coarse textured (finer than red lauaan), cross grained, soft to moderately hard, light to moderately heavy; specific gravity, 0.575.

Microscopic features.—Vessels medium to large, 191 to 294 μ (average, 226) in diameter, oblong or rarely rounded in transverse section. Tracheids less prominent than in red lauaan. Fiber tracheids wanting. Libriform fibers smaller than in red lauaan, 25 by 1,470 μ, with walls 2.5 μ in thickness, arranged in distinct radial rows. Vertical parenchyma vasicentric and diffuse as in *Parashorea*. Resin cysts distinct, in interrupted concentric lines. Idioblasts wanting. Wood rays variable; those of soft grades narrow and high (3 by 50 cells). Ray parenchyma heavily impregnated with gummy infiltration products, comparable to that of red lauaan in this respect.

Remarks.—Used for high-grade furniture, cases for musical and scientific instruments, and aëroplane propellers. According to tests conducted at the Forest Products Laboratory[40] at

[38] Foxworthy, F. W., Philippine Dipterocarpaceae, Philip. Journ. Sci. § C 6 (1911) 275.

[39] Specimens grown in western Luzon are occasionally dark red to reddish brown and are often of greater density.

[40] Heck, G. E., and Dennis, C. E., jr., Mechanical and physical properties of tangile, U. S. Forest Products Laboratory, mimeographed November 20, 1918.

Madison, Wisconsin, tangile is approximately 14 per cent greater in weight or density than true mahogany. It was also found that the "mechanical properties of tangile compare favorably with those of true mahogany." Not durable when exposed to the weather or in contact with the ground. Tangile is known by several trade names outside the Islands such as "Philippine mahogany," "tangile mahogany," and "Bataan" or "Bataan mahogany."

Shorea polysperma is one of the most abundant of the red lauaans. It occurs from Cagayan southward to Cotabato and is cut in large quantities.

SUBGROUP WHITE LAUAANS

The white lauaans, as the term implies, are characterized by pale yellow to light red or pinkish wood, and include the species of *Parashorea* and *Pentacme*, and light-colored *Shorea* species that occur in the Islands. They are the most abundant of the dipterocarps and are found throughout the Archipelago wherever this type of forest occurs. The distinguishing characteristics of the wood of the most-important members are given in the following key:

Key to the genera and species of white lauaans.

1. Wood pale yellow; pores medium, average 200 μ; horizontal and vertical resin cysts present; vertical idioblasts wanting.
   Kalunti (*Shorea mindanensis*).

   Wood not of yellowish cast; pores medium to very coarse, generally average over 200 μ; horizontal resin cysts wanting; vertical idioblasts present .... 2.
2. Wood grayish or brownish, medium hard to hard, moderately heavy; average specific gravity, 0.593; tracheids prominent, 2 to 12 in number.
   Bagtikan (*Parashorea malaanonan*).

   Wood grayish white to light red or pinkish, soft to medium hard, light to moderately heavy; specific gravity rarely over 0.55; tracheids inconspicuous, 1 to 6 in number .... 3.
3. Wood light red to pinkish or often with vinaceous tinge; pores numerous, predominately oblong; idioblasts wanting or very sparse.
   Almon (*Shorea eximia*).

   Wood grayish white; pores relatively few; vertical and horizontal idioblasts numerous .... 4.
4. Wood coarse to very coarse textured; pores large, average over 300 μ in diameter; average specific gravity, 0.555; libriform fibers narrow, 25 by 1,910 μ .... **Mindanao white lauaan** (*Pentacme mindanensis*).

   Wood medium to coarse textured; pores medium to large, average less than 300 μ in diameter; average specific gravity, 0.471; libriform fibers broad, 28 by 1,450 μ .... **White lauaan** (*Pentacme contorta*).

SHOREA MINDANENSIS Foxworthy. KALUNTI. (Plate 21.)

Gross features.—Sapwood whitish, narrow, sometimes turning to grayish brown and becoming darker than the heartwood; heartwood nearly white when fresh, turning yellowish or yellowish brown on exposure. Wood fine textured and cross grained, moderately heavy, specific gravity, 0.532.

Microscopic features.—Vessels fine to medium, 59 to 250 μ (average, 200) in diameter, terete or rounded in transverse section, solitary or in groups of 2 or 3; tyloses sparse. Tracheids few. Fiber tracheids wanting. Libriform fibers numerous, medium-sized, 21 by 1,360 μ, arranged in distinct radial series. Vertical parenchyma vasicentric and diffuse, the latter inconspicuous. Resin cysts inconspicuous in interrupted concentric lines, horizontal resin cysts present. Horizontal idioblasts common; vertical idioblasts sparse or wanting. Wood rays broad and high, 6 by 100 cells.

Remarks.—Used for cheap construction, piling, and temporary structures. Not durable when exposed or in contact with the ground. Difficult to saw in spite of its softness, even in large band mills, and hence not lumbered to any extent and not well known in the market. The only Philippine dipterocarp of those studied with horizontal resin cysts.

Shorea mindanensis is confined wholly to Mindanao, where it is relatively abundant.

PARASHOREA MALAANONAN (Blanco) Merrill. BAGTIKAN. (Plates 6, 7, 8, and 22.)

Gross features.—Sapwood white, medium thick; heartwood grayish red, often with a brownish cast. Wood coarse and uneven textured,[41] cross grained, moderately hard to hard, moderately heavy; specific gravity, 0.593.

Microscopic features.—Vessels large to very large, 73 to 317 μ (average, 275) in diameter, terete to oblong in transverse section, solitary or in groups or strings of 3 to 15; tyloses sparse. Tracheids relatively abundant, proximate to the vessels. Fiber tracheids wanting. Libriform fibers numerous, medium-sized, 22 by 1,540 μ; radial arrangement less distinct than in kalunti. Vertical parenchyma vasicentric, vasicentric-zonate, or diffuse. Resin cysts in interrupted concentric rows, rarely solitary. Horizontal and vertical idioblasts present. Wood rays broad and high, 6 by 60 to 90 cells.

[41] Bagtikan is the most uneven textured of the lauaans, owing to the irregular distribution of the vessels.

Remarks.—Used for rough construction, including siding, sheathing, and concrete forms, and for cheap furniture and dugout canoes. Not durable when exposed or in contact with the soil.

Bagtikan,[42] although cut in large quantities, is sold at present as "white lauaan." It is as a rule harder and heavier and consequently stronger than white lauaan (*Pentacme contorta*) and deserves to be marketed under its own name. The wood is distinct from the other lauaans owing to its brownish cast, its relatively greater hardness and weight, and the pronounced grouping of its vessels.

Parashorea malaanonan is widely distributed throughout the Archipelago in regions where there is no pronounced dry season. It has not been reported from the northwestern part of Luzon.

SHOREA EXIMIA (Miquel) Scheffler. ALMON. (Plate 23.)

Gross features.—Sapwood yellowish white, turning dark brown upon exposure, thin; heartwood pale red, fading to pinkish red. Wood coarse to very coarse textured, cross grained, soft to moderately hard, light to moderately heavy; specific gravity, 0.514.

Microscopic features.—Vessels large to very large, 162 to 352 μ (average, 300) in diameter, oblong in transverse section, solitary or, more rarely, grouped; tyloses sparse. Tracheids few. Fiber tracheids wanting. Libriform fibers numerous, large (27 by 1,630 μ), with walls 2.5 to 4.4 μ (average, 3.5) in thickness, with distinct radial arrangement; lumina large. Vertical parenchyma vasicentric and diffuse, the latter inconspicuous. Resin cysts in interrupted concentric lines. Horizontal and vertical idioblasts wanting or sparse. Wood rays 4 or 5 by 60 to 70 cells; organic infiltration thin.

Remarks.—Used for the same purposes as white lauaan and bagtikan, for rough construction, siding, and interior finish. Not durable when exposed, but less subject to ambrosia beetles than red lauaan.

With age almon assumes a reddish or pinkish red hue, thus rendering its separation from the red lauaans difficult except through microscopic features. Curly or mottled grades of almon are marketed as "curly bagtikan."

[42] The wood known in the market as "curly" or "birdseye" bagtikan is *Shorea eximia*.

Shorea eximia is reported from the eastern part of Luzon southward to Zamboanga, but like *Parashorea* is confined to regions where a dry season is not pronounced.

PENTACME MINDANENSIS Foxworthy. MINDANAO WHITE LAUAAN. (Plate 24.)

Gross features.—Sapwood whitish, turning pale gray in drying; medium thick; heartwood pale grayish to grayish brown. Wood coarse to very coarse textured, cross grained, soft to moderately hard, light to moderately heavy; specific gravity, 0.555. The wood is practically identical with white lauaan except for its coarser texture.

Microscopic features.—Vessels large to very large, 117 to 412 μ (average, 320) in diameter, oblong in transverse section, solitary or in groups of 2 or 3; tyloses sparse. Tracheids 1 to 6, relatively inconspicuous. Fiber tracheids wanting. Libriform fibers numerous, large (25 by 1,910 μ), radially arranged in distinct rows. Vertical parenchyma vasicentric and diffuse, the latter occasionally zonate. Resin cysts in interrupted concentric lines. Horizontal and vertical idioblasts present. Wood rays broad and relatively high, 6 or 7 by 60 cells.

Remarks.—Used for the same purposes as white lauaan and bagtikan, and in all probability identical in durability. The wood of the species is sold as white lauaan, from which it is distinguished only with difficulty.

Pentacme mindanensis is confined wholly to Mindanao, where it occurs in admixture with other dipterocarps.

PENTACME CONTORTA (Vidal) Merrill and Rolfe. WHITE LAUAAN. (Plate 25.)

Gross features.—Similar to those of Mindanao white lauaan except for the slightly finer texture and lighter weight; specific gravity, 0.471.

Microscopic features.—Vessels medium to large, 103 to 279 μ (average, 219) in diameter, terete or oblong in transverse section, solitary or in groups of 2 to 4; tyloses sparse. Tracheids few, 1 to 6, inconspicuous. Fiber tracheids wanting. Libriform fibers numerous, large (28 by 1,450 μ), in distinct radial rows, simulating the tracheids of coniferous wood; lumina broad. Vertical parenchyma vasicentric and diffuse; inconspicuous and difficult to identify in transverse section from the thin-walled libriform fibers. Resin cysts in interrupted concentric lines, inconspicuous. Horizontal and vertical idioblasts present. Wood rays varying directly according to density.

Dense specimens from western Luzon exhibit broad rays (9 by 55 cells), while in light samples they are restricted in size (4 by 45 cells).

Remarks.—This species furnishes the bulk of the white lauaan of the trade and is used extensively for rough construction, cheap furniture, and other purposes when strength and durability are not essential. The better grades are undoubtedly mixed with almon and bagtikan and reach the foreign market as "Philippine" or "white mahogany."

Pentacme contorta is widely distributed throughout the Archipelago, growing in admixture with other dipterocarps and forming heavy stands.

THE YAKÁL GROUP

The yakál group comprises the harder and heavier dipterocarps belonging to the genera *Hopea, Shorea, Balanocarpus,* and *Isoptera,* and is to be regarded as purely arbitrary. It approaches most closely the manggachapuí group but differs in the greater weight, hardness, and durability, and the darker color of its woods. The first two genera contain numerous species and are represented in other groups. Only two species of *Balanocarpus* and one of *Isoptera* are known to occur in the Philippines, and these are wholly confined to the yakál group.

Gross features.—Sapwood pale grayish white, variable in thickness; heartwood pale yellow when first exposed, turning to shades of yellow, brown, or reddish brown. In addition *Hopea mindanensis* and *Balanocarpus cagayanensis* exhibit greenish streaks which assume the form of concentric bands. Wood very fine to medium textured, straight or cross grained, hard to very hard, and heavy to very heavy; specific gravity, 0.80 to 1.20.

Microscopic features.—Vessels very small to medium, 67 to 180 μ in diameter, terete to oblong in transverse section, solitary or grouped; tyloses abundant, very conspicuous. Tracheids present or wanting. Fiber tracheids wanting. Libriform fibers numerous, thick walled, closely packed, radially or irregularly arranged. Vertical parenchyma various, vasicentric to diffuse. Resin cysts in interrupted concentric rows, relatively inconspicuous. Idioblasts present. Wood rays narrow to medium, not exceeding 5 cells. Organic infiltration variable.

Remarks.—This group comprises the hardest and most durable of the Philippine dipterocarps, and furnishes the bulk of the heavy structural timbers of the Islands.

Key to the genera and species in the yakál group.

1. Wood when freshly cut greenish or with grass green streaks.................. 2.
 Wood neither greenish nor with grass green streaks when freshly cut..3.
2. Wood when freshly cut reddish, aside from the greenish streaks; pores medium (average, 159 μ); rays large, 4 by 95 cells; southern species. Bagususu (*Hopea mindanensis*).
 Wood when freshly cut grayish or yellowish green to grayish brown, aside from the greenish streaks; pores fine (average, 119 μ); rays small, 4 by 25 cells; northern species. Narek (*Balanocarpus cagayanensis*).
3. Texture very fine; pores small (average, 100 μ), indistinct to the naked eye; wood very hard and very heavy; specific gravity, 0.98 to 1.20; tracheids and vertical idioblasts wanting........ Yakál (*Hopea plagata*).
 Texture fine to medium; pores small to medium (average, over 100 μ), distinct to the naked eye; wood hard to very hard, heavy to very heavy; specific gravity, 0.80 to 1.05; tracheids and vertical idioblasts present .... 4.
4. Pores medium (average, 180 μ), conspicuously thick walled; tracheids and vertical parenchyma prominent; tyloses completely occluding the vessels.. Malayakal (*Isoptera borneensis*).
 Pores small (average not over 140 μ), not conspicuously thick walled; tracheids and vertical parenchyma not prominent; tyloses not completely occluding the vessels......................... Gisok (*Shorea balangeran*).

HOPEA MINDANENSIS Foxworthy. BAGASUSU. (Plate 29, fig. 2.)

Gross features.—Sapwood grayish white, subject to sap stain, thin; heartwood reddish brown with concentric greenish zones which turn nearly black with age. Wood fine to medium textured, fairly straight grained, very hard and very heavy; specific gravity, 0.849.

Microscopic features.—Vessels numerous, medium-sized, 37 to 191 μ (average, 159) in diameter, ovoid in transverse section, solitary or in groups of 2 or 3; tyloses numerous. Tracheids and fiber tracheids wanting. Libriform fibers numerous, small (19 by 1,566 μ), with walls 8.3 μ in thickness, radially arranged. Vertical parenchyma vasicentric- and diffuse-zonate, in tangential bands, connecting wood rays. Resin cysts in interrupted concentric lines. Horizontal and vertical idioblasts present, the last predominating. Wood rays medium (4 by 95 cells), dark colored with organic infiltration.

Remarks.—Used locally for structural timber, railroad ties, bridge construction, and other purposes where a strong and durable wood is required. Similar to narek but can be distinguished by the reddish tinge of the wood. Probably more durable than the manggachapuís although less lasting than the better-known yakáls. Easily distinguished from the other

yakáls by the greenish cast of the wood, but little known and consequently bringing a low price in the local markets.

Hopea mindanensis is reported to be fairly common in southern Mindanao, where it is lumbered in limited quantities; it is wholly confined to that island.

BALANOCARPUS CAGAYANENSIS Foxworthy. NAREK. (Plate 29, fig. 1.)

Gross features.—Sapwood pale green, thick; heartwood yellowish to dark green, with distinct concentric bands of grass green streaks. Wood very fine textured, straight grained, hard to very hard, heavy to very heavy; specific gravity, 0.833.

Microscopic features.—Vessels numerous, small, 51 to 166 μ (average, 119) in diameter, terete to oval or ovoid, solitary or in groups of 2 or 3; tyloses prominent. Tracheids and fiber tracheids wanting. Libriform fibers numerous, small (18 to 1,380 μ) with walls 6.5 μ in thickness, somewhat radially arranged. Vertical parenchyma prominent, vasicentric- to diffuse-zonate. Resin cysts in interrupted concentric lines. Horizontal and vertical idioblasts present, the latter predominating. Wood rays small (3 or 4 by 35 cells).

Remarks.—Used for house posts and permanent construction where strength and durability are required. Little known except in the local markets of northern Luzon, where it is used extensively for house posts.

Balanocarpus cagayanensis is a tree of medium size and has been reported only from Cagayan Province, Luzon.

HOPEA PLAGATA Vidal. YAKÁL. (Plate 31, fig. 2.)

Gross features.—Sapwood pale yellow when fresh, turning to dirty gray upon exposure, medium thick; heartwood pale yellow to yellowish brown. Wood very fine to fine textured, fairly straight grained, extremely hard and heavy; specific gravity, 0.99 to 1.20.

Microscopic features.—Vessels numerous, very small to small, 44 to 88 μ (average, 67) in transverse section, terete to oval or ovoid, in groups of 2 or 3; tyloses prominent, completely occluding the pores. Tracheids and fiber tracheids wanting. Libriform fibers numerous, small (13.6 by 1,360 μ), with walls 6.9 μ in thickness, radially arranged. Vertical parenchyma vasicentric and diffuse-zonate, the latter usually in tangential rows, one cell in thickness. Resin cysts in interrupted concentric lines, inconspicuous. Vertical idioblasts wanting; horizontal

idioblasts very numerous and prominent, often making up the whole ray. Wood rays small (3 by 30 to 40 cells); infiltration sparse.

Remarks.—Used for permanent construction such as houses, bridges, wharves, and railroad ties owing to its great strength and durability. Often mistaken for *Vatica* but distinguished by the concentric rows of resin cysts and diffuse-zonate parenchyma.

Hopea plagata is very widely distributed in Luzon, from Cagayan southward to Sorsogon. Also reported from Mindoro southward to Basilan.

ISOPTERA BORNEENSIS Scheffler. MALAYAKAL. (Plate 26.)

Gross features.—Sapwood light gray, medium thick; heartwood pale grayish to yellowish gray. Wood fine to medium textured, cross grained, hard to very hard, heavy to very heavy; specific gravity, 0.734?

Microscopic features.—Vessels numerous, medium sized, 44 to 250 μ (average, 180) in transverse section, rounded to oblong, thick walled, solitary or in groups of 2 to 4; tyloses very prominent, completely occluding the pores. Tracheids numerous but less so than in *Parashorea.* Fiber tracheids absent. Libriform fibers numerous, medium-sized (18 to 1,480 μ), with walls 8.3 μ in thickness, in indistinct radial rows. Vertical idioblasts present. Horizontal idioblasts wanting. Rays small (4 by 35 cells). Organic infiltration conspicuous.

Remarks.—A very strong and durable wood, and for this reason largely employed in permanent construction where strength and durability are essential. Used for the same purposes as *Hopea plagata,* and probably the source of the bulk of the yakál timber of the market.

Isoptera borneensis is reported from Camarines, southern Luzon, southward to Samar and Mindanao, where it forms extensive stands in Zamboanga.

SHOREA BALANGERAN (Korthals) Dyer. GISOK. (Plate 27.)

Gross features.—Very similar to malayakal. Sapwood light gray, medium thick; heartwood grayish to yellowish gray. Wood fine textured, cross grained, hard to very hard, heavy to very heavy; specific gravity, 1.05.

Microscopic features.—Vessels scattered, small, 73 to 191 μ (average, 138) in diameter, rounded to oval, solitary or in groups of 2 or 3; tyloses numerous. Tracheids few, 1 or 2, proximate to vessels. Fiber tracheids wanting. Libriform fibers numerous, small (18 by 1,480 μ), with walls 7 μ in thick-

ness, arranged in distinct radial rows. Vertical parenchyma vasicentric- to diffuse-zonate. Resin cysts in interrupted concentric rows. Vertical idioblasts present. Horizontal idioblasts wanting. Wood rays small (3 or 4 by 60 cells); organic infiltration conspicuous.

Remarks.—Used for permanent construction, shipbuilding, and bridges, owing to its strength and durability. One of the best structural timbers of the Islands and obtainable in quantity in large sizes.

Shorea balangeran is reported from Luzon southward to Zamboanga and reaches the local markets in appreciable quantities.

SHOREA GUISO (Blanco) Blume. GIHO. (Plate 28.)

Gross features.—Sapwood light gray, thin; heartwood reddish brown to brown. Wood fine to medium textured; cross grained, medium hard to hard, moderately heavy to heavy; specific gravity, 0.812.

Microscopic features.—Vessels numerous, small, 64 to 205 μ (average, 137) in diameter, rounded or oblong, solitary or in groups of 2 or 3; tyloses sparse. Tracheids rare. Fiber tracheids wanting. Libriform fibers numerous, small (19 by 1,370 μ), with walls 6.4 μ in thickness, arranged in radial rows. Vertical parenchyma vasicentric to vasicentric-zonate, occasionally diffuse. Resin cysts in interrupted concentric rows. Vertical idioblasts prominent. Horizontal idioblasts wanting. Wood rays small (3 or 4 by 40 cells). Organic infiltration copious, especially in the wood rays.

Remarks.—Used for general construction, houses, and is the favorite wood for vehicle parts. Not durable when exposed or in contact with the soil. Probably the best-known dipterocarp of the Islands, not only on account of its wide distribution but also because of the general utility of the wood. Often substituted for the coarse-textured yakáls such as gisok and malayakal, from which it differs in its lighter, softer, reddish (in contrast to yellowish gray) wood. On the other hand, the apitongs are substituted for it in the market but are to be distinguished in that the various species of *Dipterocarpus* are coarse textured and exhibit diffuse resin cysts.

Shorea guiso is widely distributed throughout the Archipelago from Cagayan southward to Zamboanga.

THE MANGGACHAPUÍ GROUP

The manggachapuí group is wholly confined to the genus *Hopea* and takes its name from the best-known species, *Hopea*

acuminata. The wood resembles the finer-grained yakáls of the genera *Hopea* and *Balanocarpus,* but differs from these largely in hardness, weight, and durability.

Gross features.—Sapwood pale white, variable in thickness; heartwood pale grayish yellow turning to golden yellow or russet in contrast to the yakáls, which assume a much darker hue. Wood very fine or fine textured, straight or rarely cross grained, moderately hard to hard, moderately heavy to heavy; specific gravity, 0.680 to 0.844.

Microscopic features.—Vessels small to medium (145 to 167 μ in diameter), terete or oblong in transverse section, solitary or grouped; tyloses not abundant. Tracheids and fiber tracheids wanting. Libriform fibers numerous, variously arranged. Vertical parenchyma vasicentric to diffuse-zonate. Resin cysts in interrupted concentric lines, not conspicuous. Idioblasts present. Wood rays narrow (not exceeding 5 cells). Organic infiltration variable.

Remarks.—The manggachapuí group comprises the soft, finer-textured dipterocarps. They are neither so strong nor so durable as the yakáls, but are used locally as structural timbers where woods of moderate strength and durability are required. Not obtainable in large quantity.

Key to the species in the manggachapuí group.

1. Pores numerous, in groups of 2 to 5; vertical parenchyma prominently diffuse-zonate, forming concentric bands; trees of small or medium size with thick sapwood................ Gisok-gisok (*Hopea philippinensis*).
   Pores relatively few, solitary or in groups of 2 or 3; vertical parenchyma prominently vasicentric or inconspicuously diffuse-zonate; trees of medium or large size, with thin sapwood.. 2.
2. Libriform fibers in distinct radial rows; vertical idioblasts wanting. Manggachapuí (*Hopea acuminata*).
   Libriform fibers not radially arranged; horizontal and vertical idioblasts present, the latter predominating........ Dalingdingan (*Hopea pierrei*).

HOPEA PHILIPPINENSIS Dyer. GISOK-GISOK. (Plate 30, fig. 2.)

Gross features.—Sapwood pale white, thick; heartwood pale grayish yellow turning to russet upon drying, restricted owing to the small size of the tree. Wood fine to medium textured, straight grained, moderately hard to hard, moderately heavy to heavy; specific gravity, 0.771.

Microscopic features.—Vessels numerous, small to medium sized, 80 to 191 μ (average, 145) in diameter, terete to oblong or ovoid in transverse section, generally in groups of 2 to 5;

tyloses sparse. Tracheids and fiber tracheids wanting. Libriform fibers numerous, small (19 by 1,320 μ), irregularly arranged. Vertical parenchyma vasicentric to diffuse-zonate, the latter conspicuous. Resin cysts in interrupted concentric lines. Both horizontal and vertical idioblasts present, the vertical predominating. Wood rays medium sized (4 by 70 cells). Organic infiltration inconspicuous.

Remarks.—Used locally for posts and piling, rarely sawn into lumber owing to the small size of the trees.

Hopea philippinensis is widely distributed throughout the Islands from Laguna, southern Luzon, southward to Basilan, in regions where precipitation is evenly distributed throughout the year.

HOPEA ACUMINATA Merrill. MANGGACHAPUÍ. (Plate 30, fig. 1.)

Gross features.—Sapwood pale white, thin, susceptible to dark brown sap stain; heartwood pale grayish yellow, turning to golden brown or russet upon exposure. Wood fine to medium textured, fairly straight grained, moderately hard and heavy; specific gravity, 0.783.

Microscopic features.—Vessels scattered, small to medium sized, 103 to 191 μ (average, 167) in diameter, rounded to ovoid or oblong in transverse section. Solitary or in occasional groups of 2 or 3; tyloses sparse. Tracheids and fiber tracheids wanting. Libriform fibers numerous, small (18 by 1,290 μ), with walls 4 or 5 μ in thickness, in distinct radial rows. Vertical parenchyma vasicentric, occasionally diffuse. Resin cysts in interrupted concentric lines, not conspicuous. Horizontal idioblasts present. Vertical idioblasts wanting or inconspicuous. Wood rays small (4 by 50 cells). Organic infiltration inconspicuous.

Remarks.—Used for bridges, medium-grade furniture, and rough construction where wood of medium strength and durability will suffice. Manggachapuí is a favorite wood for door and window frames. It is one of the best-known woods for shipbuilding. Less durable than the yakáls. Supply limited.

Hopea acuminata is widely distributed throughout the Archipelago, from northern Luzon to southern Mindanao. See remarks under *Anisoptera thurifera*.

HOPEA PIERREI Hance. DALINGDIÑGAN. (Plate 31, fig. 1.)

Gross features.—Sapwood similar to that of manggachapuí; heartwood pale yellowish, turning to russet upon exposure.

Wood fine to medium textured, fairly straight grained, moderately hard to hard, moderately heavy to heavy; specific gravity, 0.793.

Microscopic features.—Vessels numerous, small, 44 to 170 μ (average, 147) in diameter, rounded to oblong in transverse section, solitary or in occasional groups of 2; tyloses sparse. Tracheids and fiber tracheids wanting. Libriform fibers numerous, small (17 by 1,370 μ), with walls 4.4 μ in thickness, in indistinct radial rows. Vertical parenchyma vasicentric but tending toward diffuse-zonate; diffuse parenchyma sparse, inconspicuous. Resin cysts in interrupted, concentric lines, inconspicuous. Horizontal and vertical idioblasts present, the latter predominating. Wood rays small (4 by 80 cells). Organic infiltration scanty.

Remarks.—Used for the same purposes as *Hopea acuminata*, which it resembles in gross characters, but separated microscopically according to the features enumerated in the key.

Hopea pierrei occurs throughout the Islands from northern Luzon to northern Mindanao, but is best known in Laguna and Tayabas Provinces, Luzon.

ILLUSTRATIONS

[The photomicrographs and drawings for Plates 2 to 31 were made by Luis J. Reyes. Etchings furnished by the Bureau of Forestry.]

PLATE 1

A typical dipterocarp forest showing the characteristic habits of trees. Most of the trees in this type of forest are red lauaan (*Shorea negrosensis*), tangile (*Shorea polysperma*), bagtikan (*Parashorea malaanonan*), and white lauaan (*Pentacme contorta*).

PLATE 2. PARASHOREA MALAANONAN, ELEMENTS OF THE WOOD; × 4,000

FIG. 1. A libriform or wood fiber. Note the great length, the thickness of the wall, and the paucity of the pits.

2. Ray or horizontal idioblasts. Note the crystals of calcium oxalate and the thin membranelike wall separating them.
3. A ray or horizontal parenchyma cell with gummy infiltration.
4. An epithelial cell as seen in cross section. Note the simple pits which show its parenchymatous origin.
5. An epithelial cell as seen in longitudinal section.
6. A string of wood or vertical parenchyma cells. Note the large pits which are present whenever these cells abut tracheids or vessels.
7. A string of wood parenchyma cells. Note the small simple pits which are present when these cells abut similar parenchymatous cells.
8. A vessel segment. Note the two types of pits which are present as in fig. 6.
9. A string of vertical idioblasts. Note the simple pits which show their parenchymatous origin.
10. A tracheid showing two kinds of pits. The large ones are pits leading from tracheids to parenchymatous cells, while the smaller ones lead from tracheids to similar tracheids or other prosenchymatous cells. (See figs. 6 and 8.)
11. A tracheid showing numerous, small, bordered pits.

PLATE 3

Parashorea wood, a cross section, showing relationship of the elements in greater detail; × 264.

PLATE 4

Parashorea wood, a cross section, showing prominent tyloses which largely inhibit the passage of air and liquids in the vessels; × 200.

PLATE 5. DIAGRAMMATIC PRESENTATION OF THE FORMATION OF RESIN CANALS, SHOWING THEIR SCHIZOGENOUS NATURE; × 270

FIG. 1. The splitting apart of four wood parenchyma cells.

2. A more-advanced stage of development, showing six epithelial cells.

FIG. 3. A typical mature resin duct, showing a wide cavity lined with ten epithelial cells.

4. A tracheid adjoining a vessel (*v*) and similar tracheids (*tr*), showing the characteristic pits (*p*) leading from a tracheid to a vessel. Camera lucida drawing; × 2,260.

PLATE 6

Parashorea malaanonan, radial section of wood, *22677 B. F.*; × 50. Note the heterogeneous cells composing the wood or pith rays.

PLATE 7

Parashorea malaanonan, radial section of wood, *22677* B. F.; × 200. Showing idioblasts with calcium oxalate crystals in them.

PLATE 8

Parashorea malaanonan, tangential section, *22677 B. F.*; × 50.

PLATE 9

FIG. 1. Longitudinal view of a bordered pit leading from one vessel to another vessel.

2. Longitudinal view of a bordered pit leading from a vessel to a tracheid.
3. Lateral view of a bordered pit leading from vessel to vessel.
4. Longitudinal view of a semibordered pit leading from a vessel to a wood or vertical parenchyma.
5. Longitudinal view of a semibordered pit leading from tracheid to parenchyma.
6. Longitudinal view of a bordered pit leading from a tracheid to another tracheid.
7. Longitudinal view of a bordered pit leading from a vessel to a libriform fiber. Note the reduced size of the pit in the vessel wall.
8. Longitudinal view of a semibordered pit leading from a libriform fiber to a wood parenchyma.
9. Longitudinal view of a bordered pit leading from a libriform fiber to another libriform fiber.
10. Vertical view of a bordered pit.
11. Vertical view of simple pits.
12. Longitudinal view of simple pits leading from wood parenchyma to parenchyma cells.

PLATE 10

Vatica mangachapoi Blanco, cross section of wood, *9043 B. F.*; × 50.

PLATE 11

Dipterocarpus grandiflorus Blanco, cross section of wood, *17581 B. F.*; × 50.

PLATE 12

Dipterocarpus vernicifluus Blanco, cross section of wood, *2131 B. F.*; × 50.

PLATE 13

Dipterocarpus lasiopodus Perkins, cross section of wood, *2031 Merrill*; × 50.

PLATE 14

Anisoptera thurifera (Blanco) Blume, cross section of wood, *17585 B. F.*; × 50.

PLATE 15

Anisoptera curtisii Dyer, cross section of wood, *8985 B. F.*; × 50.

PLATE 16

Shorea palosapis (Blanco) Merrill, cross section of wood, *20708 B. F.*; × 50.

PLATE 17

Shorea teysmanniana Dyer, cross section of wood, *27041 B. F.*; × 50.

PLATE 18

Shorea negrosensis Foxworthy, cross section of wood, *17490 B. F.*; × 50.

PLATE 19

Shorea polysperma (Blanco) Merrill, cross section of wood, *17468 B. F.* from Negros; × 50. Vessels here are more numerous and the libriform fibers are thinner walled than in specimens from Bataan.

PLATE 20

Shorea polysperma (Blanco) Merrill, cross section of wood, *6324 B. F.* from Bataan; × 50. Note the thick-walled libriform fibers and the fewer vessels as compared with Plate 19 of Negros wood.

PLATE 21

Shorea mindanensis Foxworthy, cross section of wood, *9372 B. F.*; × 50.

PLATE 22

Parashorea malaanonan (Blanco) Merrill, cross section of wood, *22677 B. F.*, showing the distribution of pores, vertical or wood parenchyma, and resin canals; × 50.

PLATE 23

Shorea eximia Scheffler, cross section of wood, *17490 B. F.*; × 50.

PLATE 24

Pentacme mindanensis Foxworthy, cross section of wood, *25193 B. F.*; × 50.

PLATE 25

Pentacme contorta (Vidal) Merrill and Rolfe, cross section of wood, *5961 B. F.*; × 50.

PLATE 26

Isoptera borneensis Scheffler, cross section of wood, *9374 B. F.*; × 50.

PLATE 27

Shorea balangeran (Korthals) Dyer, cross section of wood, *15002 B. F.*; × 50. The prominent dark spots are calcium oxalate crystals.

PLATE 28

Shorea guiso (Blanco) Blume, cross section of wood, *5387 B. F.*; × 50.

PLATE 29

FIG. 1. *Balanocarpus cagayanensis* Foxworthy, cross section of wood, *26624 B. F.*; × 50.

2. *Hopea mindanensis* Foxworthy, cross section of wood, *9376 B. F.*; × 50.

PLATE 30

FIG. 1. *Hopea acuminata* Merrill, cross section of wood, *17595 B. F.*; × 50.

2. *Hopea philippinensis* Dyer, cross section of wood, *9376 B. F.*; × 50.

PLATE 31

FIG. 1. *Hopea pierrei* Hance, cross section of wood, *17771 B. F.*; × 50. Note the peculiar disposition of parenchyma cells which tend to bunch themselves on one side of the vessel.

2. *Hopea plagata* Vidal, cross section of wood, *22167 B. F.*; × 50.

PLATE 1. LARGE DIPTEROCARPS IN NORTHERN NEGROS.

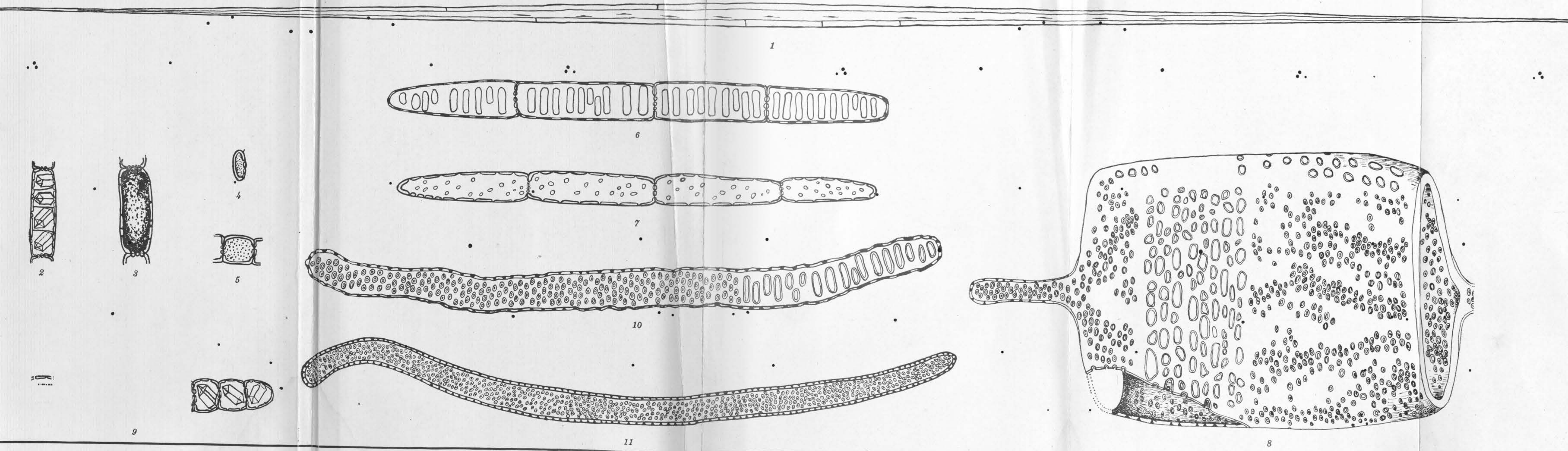

PLATE 2. PARASHOREA MALAANONAN, ELEMENTS OF THE WOOD; × 4,000.

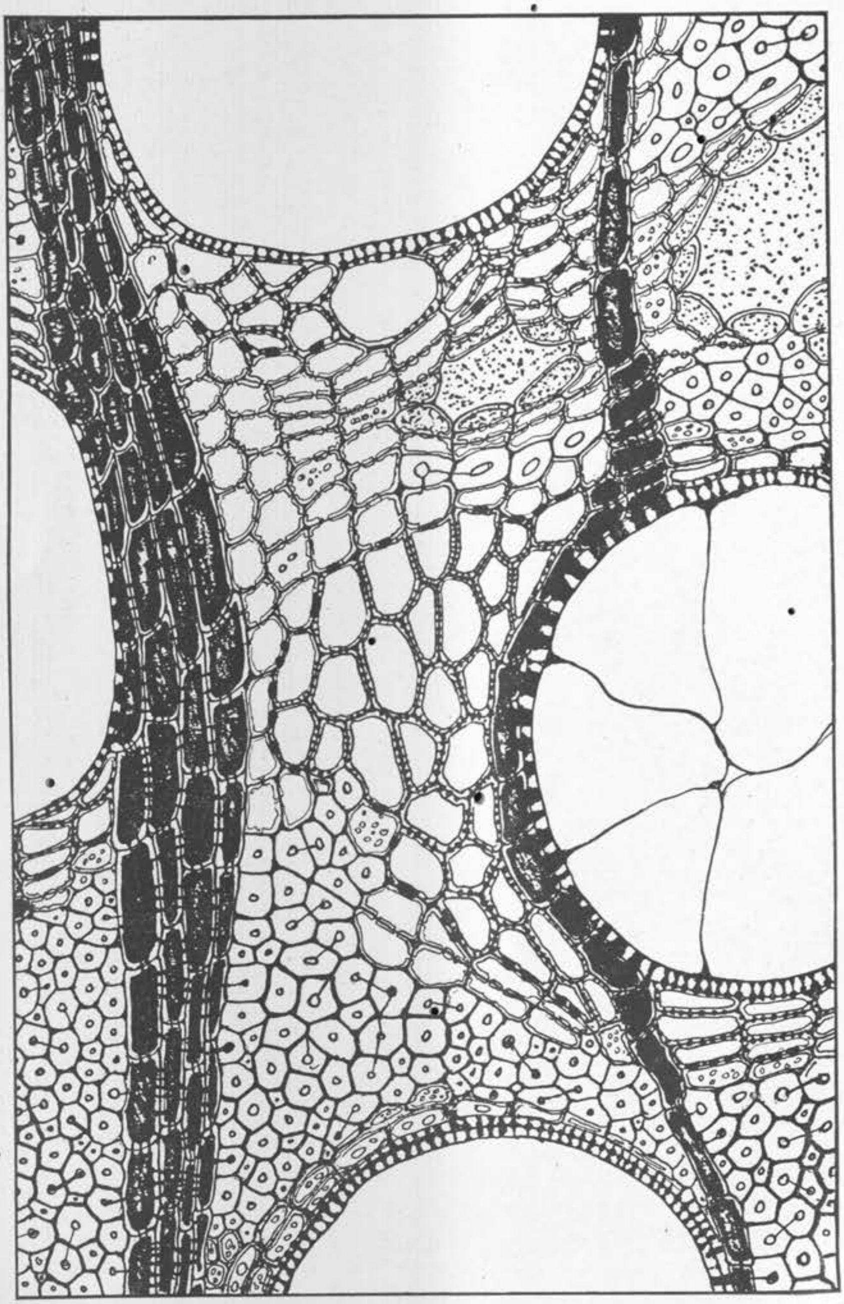

PLATE 3. A CROSS SECTION OF PARASHOREA WOOD.

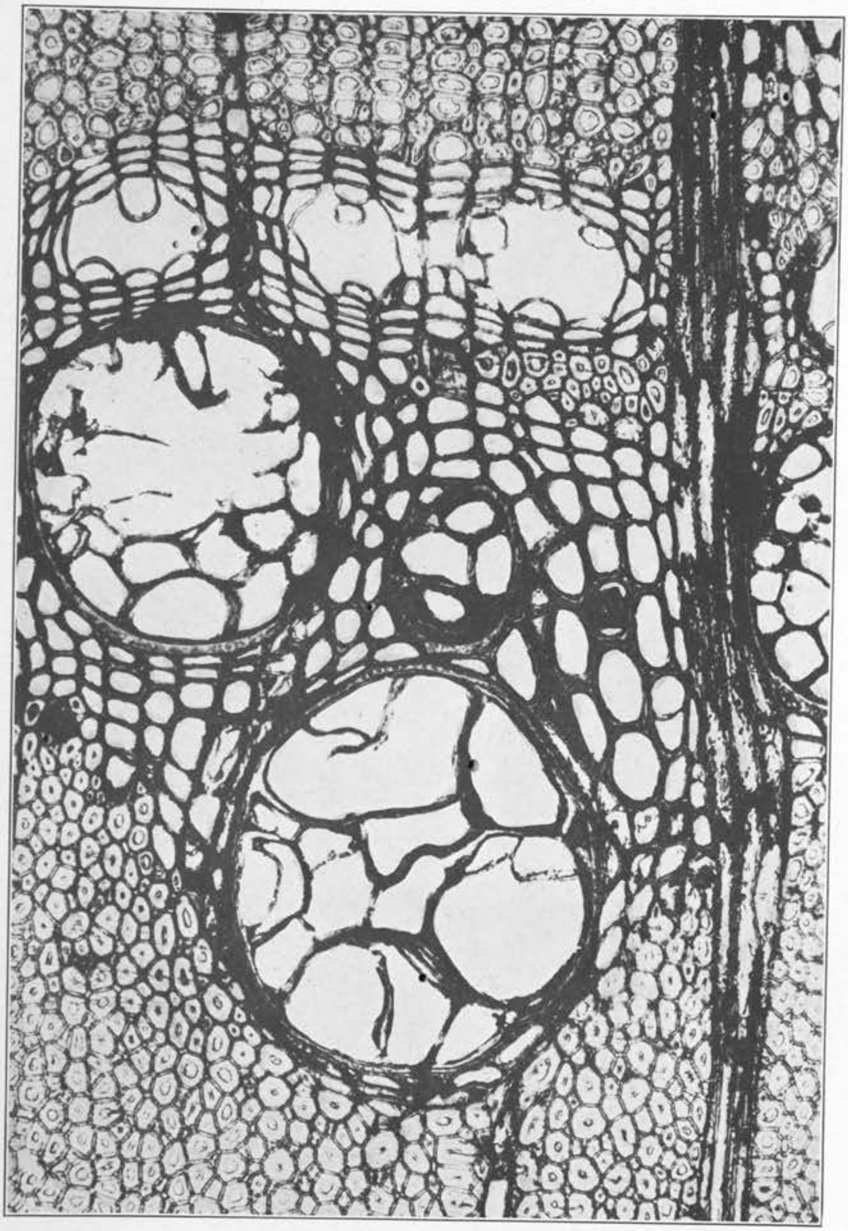

PLATE 4. A CROSS SECTION OF PARASHOREA WOOD.

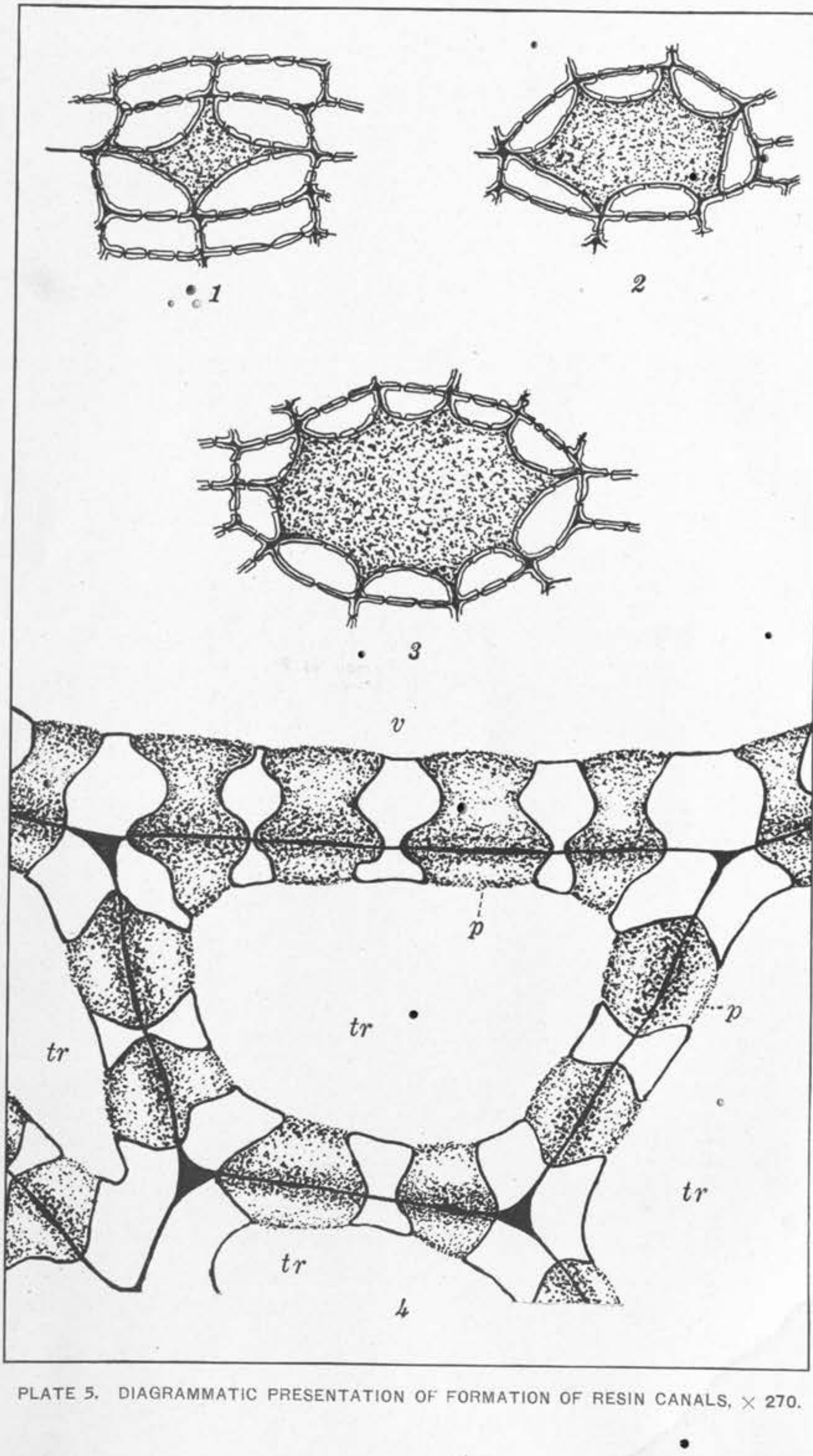

PLATE 5. DIAGRAMMATIC PRESENTATION OF FORMATION OF RESIN CANALS, × 270.

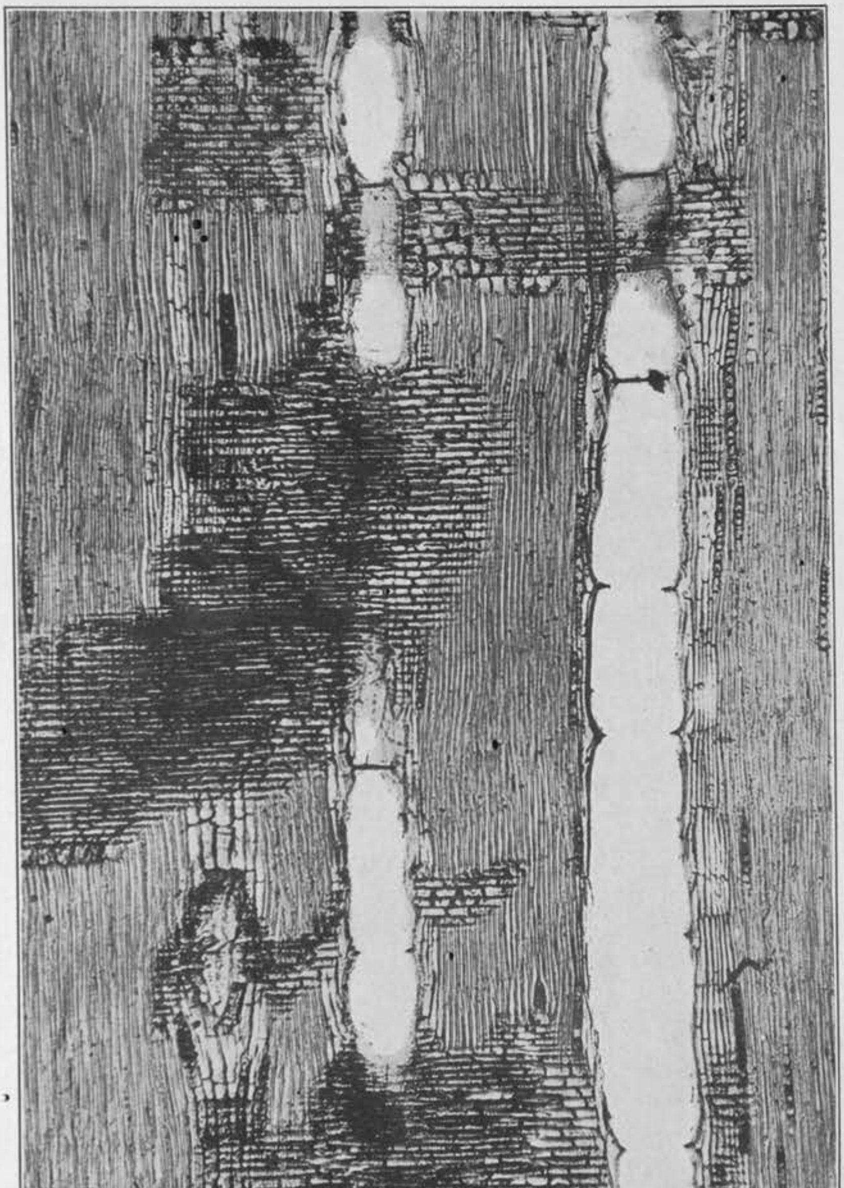

PLATE 6. RADIAL SECTION OF WOOD OF PARASHOREA MALAANONAN, × 50.

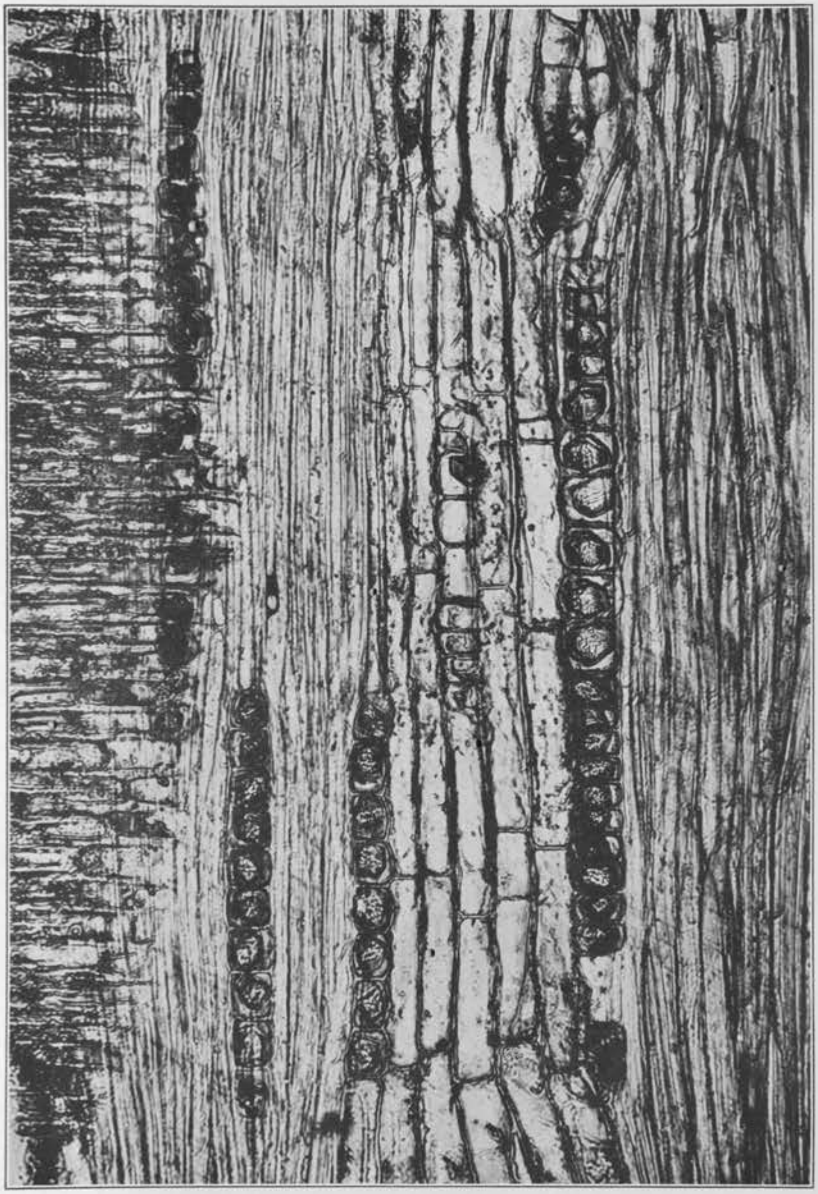

PLATE 7. RADIAL SECTION OF WOOD OF PARASHOREA MALAANONAN, × 200.

PLATE 8. TANGENTIAL SECTION OF WOOD OF PARASHOREA MALAANONAN, × 50.

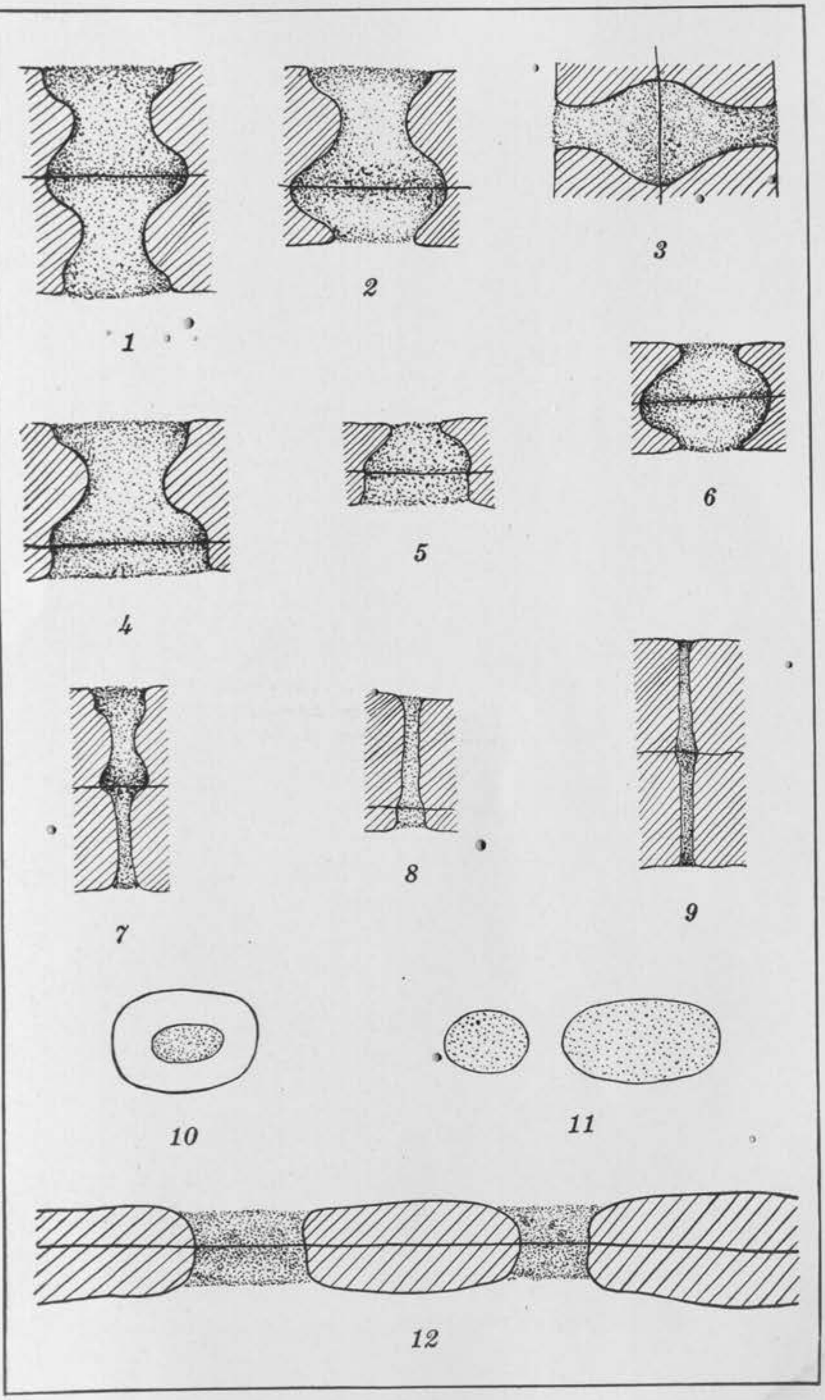

PLATE 9. BORDERED, SEMIBORDERED, AND SIMPLE PITS.

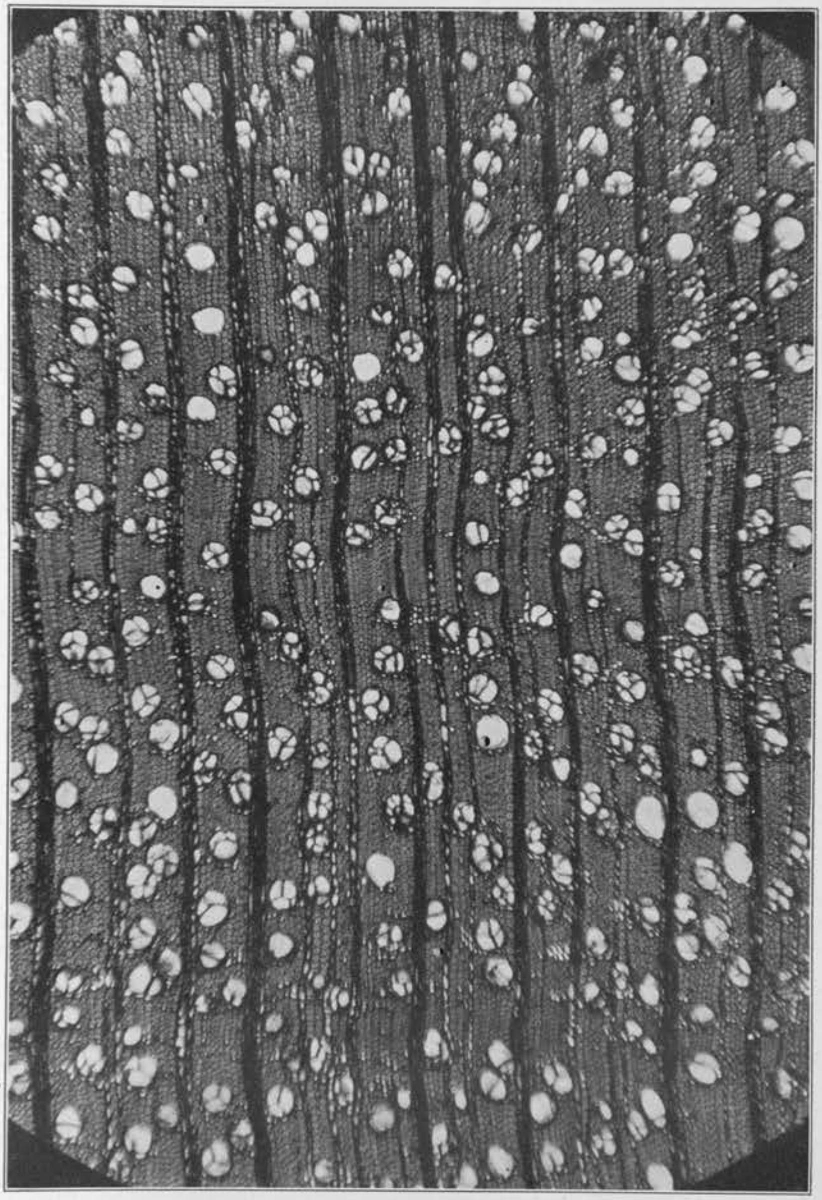

PLATE 10. CROSS SECTION OF WOOD OF VATICA MANGACHAPOI, × 50.

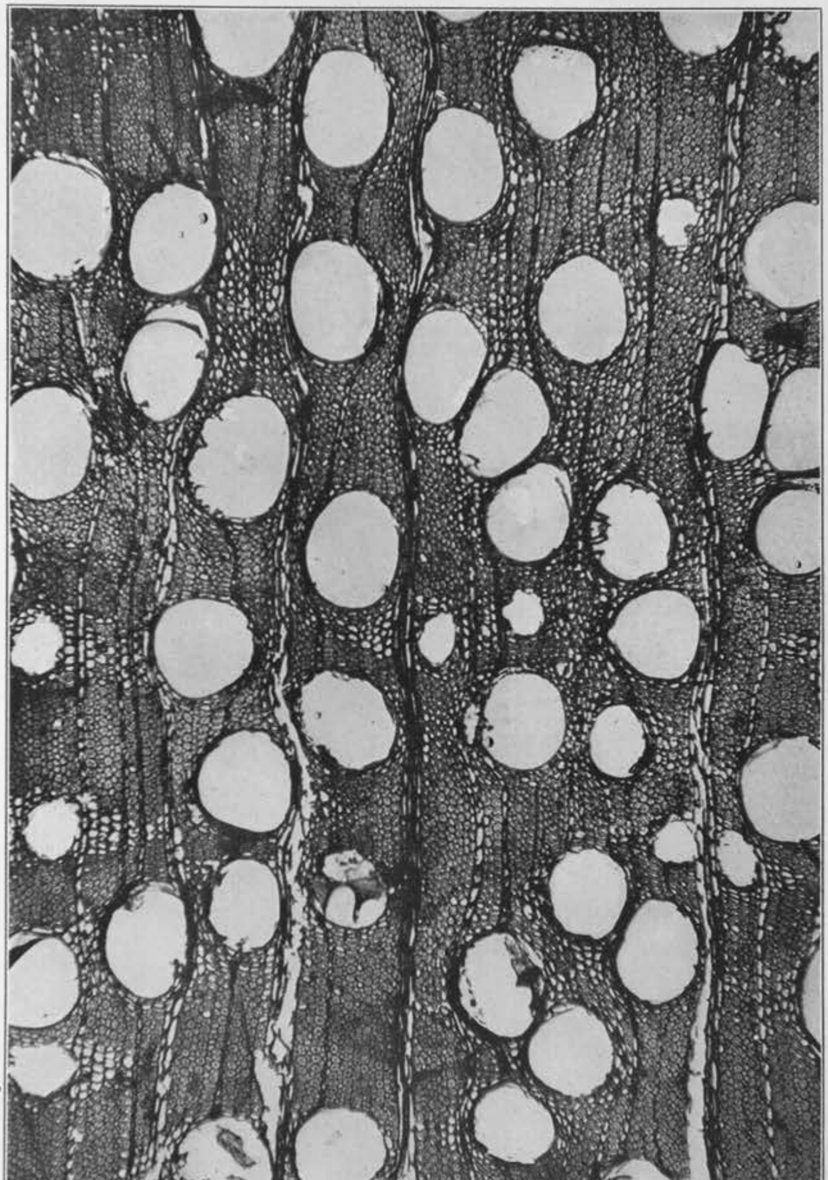

PLATE 11. CROSS SECTION OF WOOD OF DIPTEROCARPUS GRANDIFLORUS, × 50.

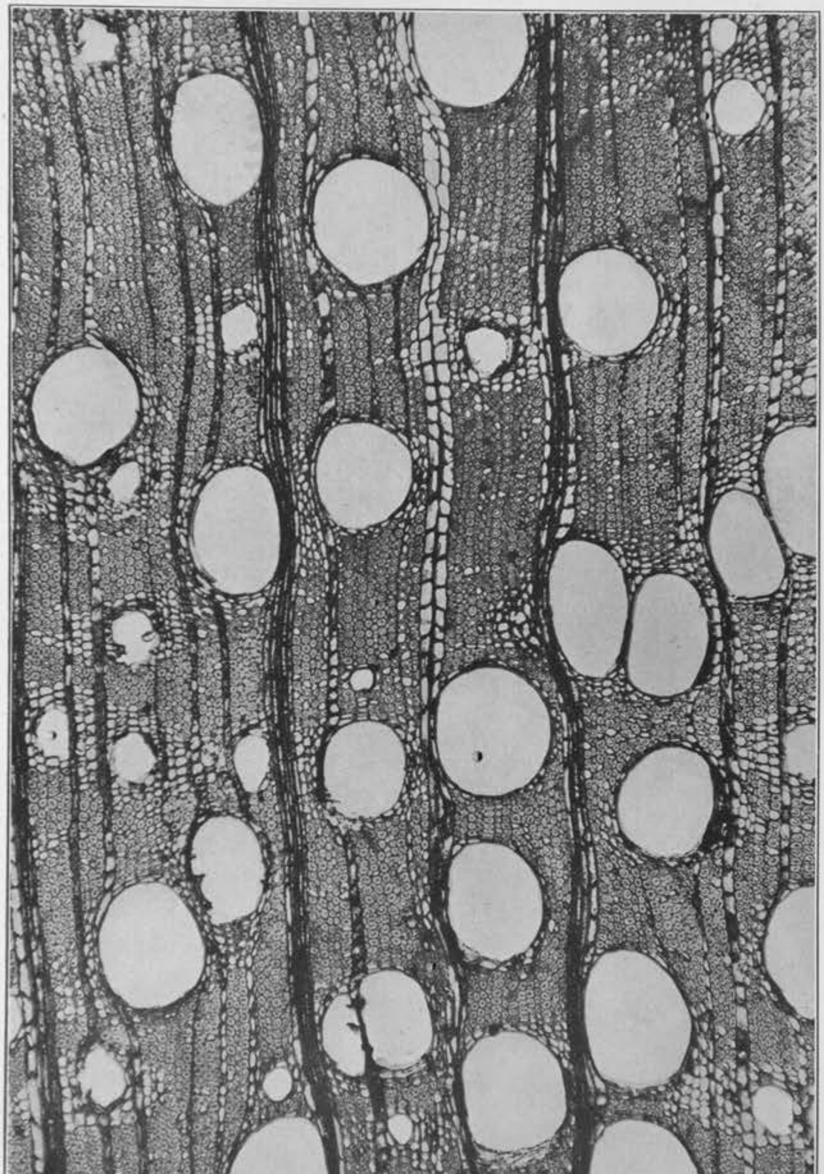

PLATE 12. CROSS SECTION OF WOOD OF DIPTEROCARPUS VERNICIFLUUS, × 50.

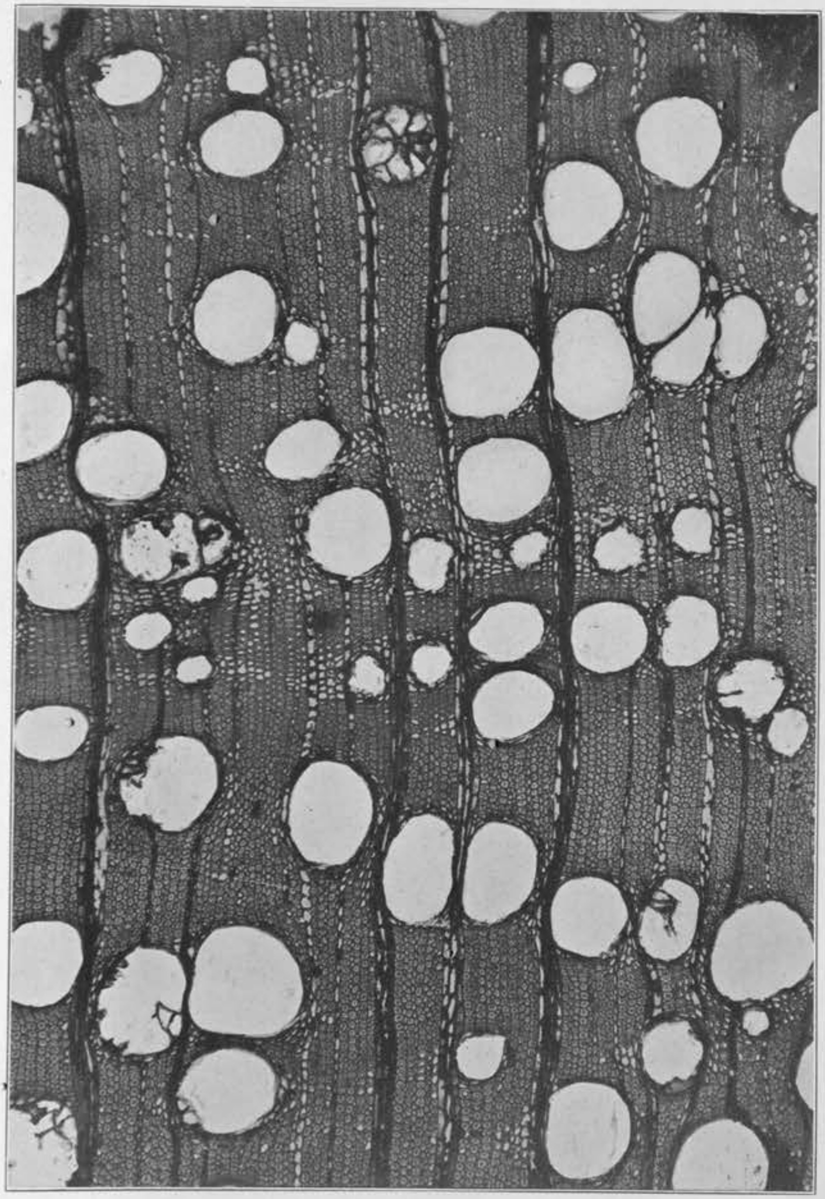

PLATE 13. CROSS SECTION OF WOOD OF DIPTEROCARPUS LASIOPODUS, × 50.

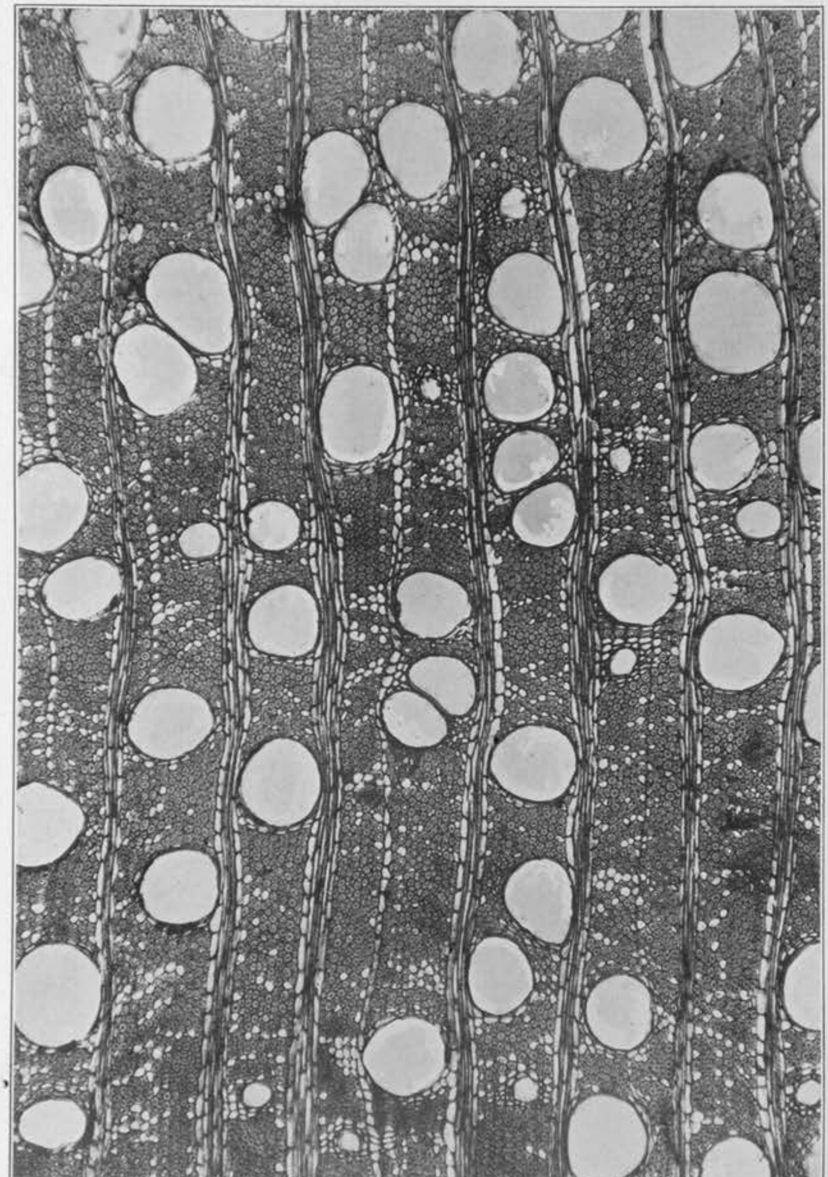

PLATE 14. CROSS SECTION OF WOOD OF ANISOPTERA THURIFERA, × 50.

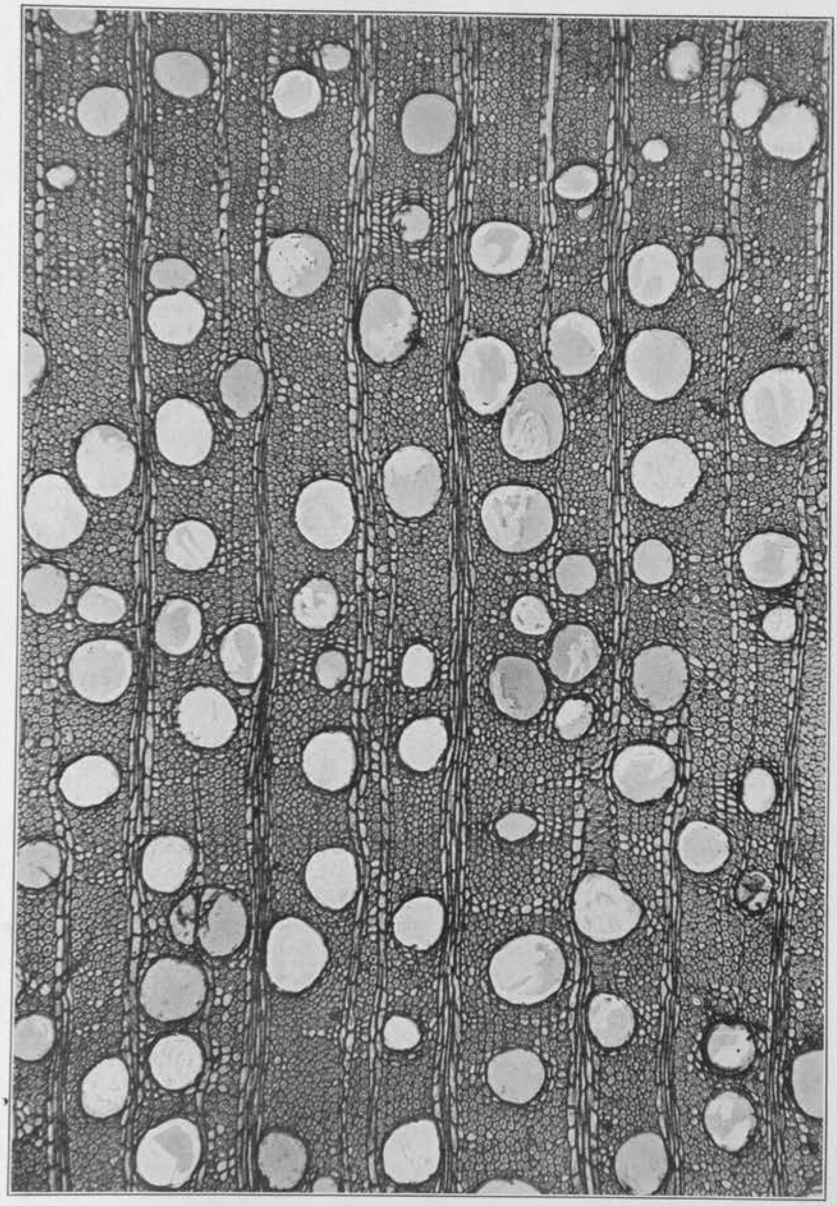

PLATE 15. CROSS SECTION OF WOOD OF ANISOPTERA CURTISII, × 50.

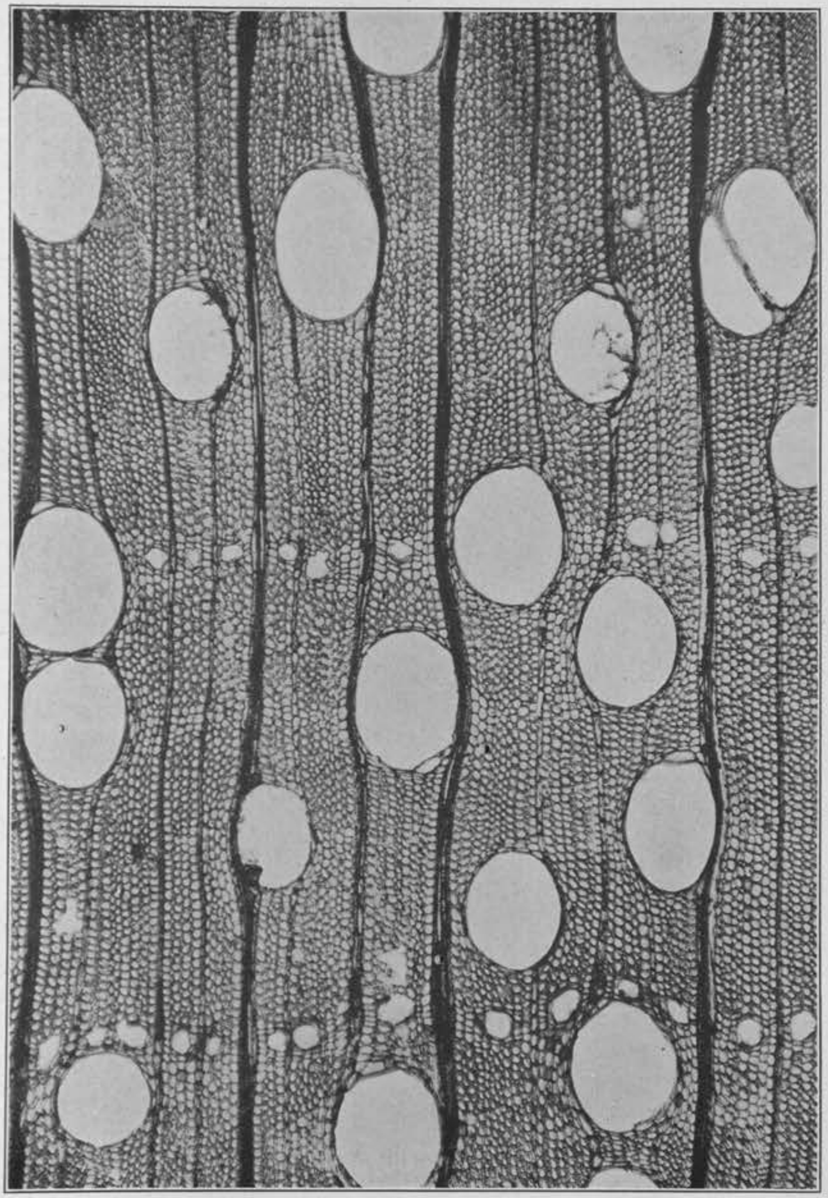

PLATE 16. CROSS SECTION OF WOOD OF SHOREA PALOSAPIS, × 50.

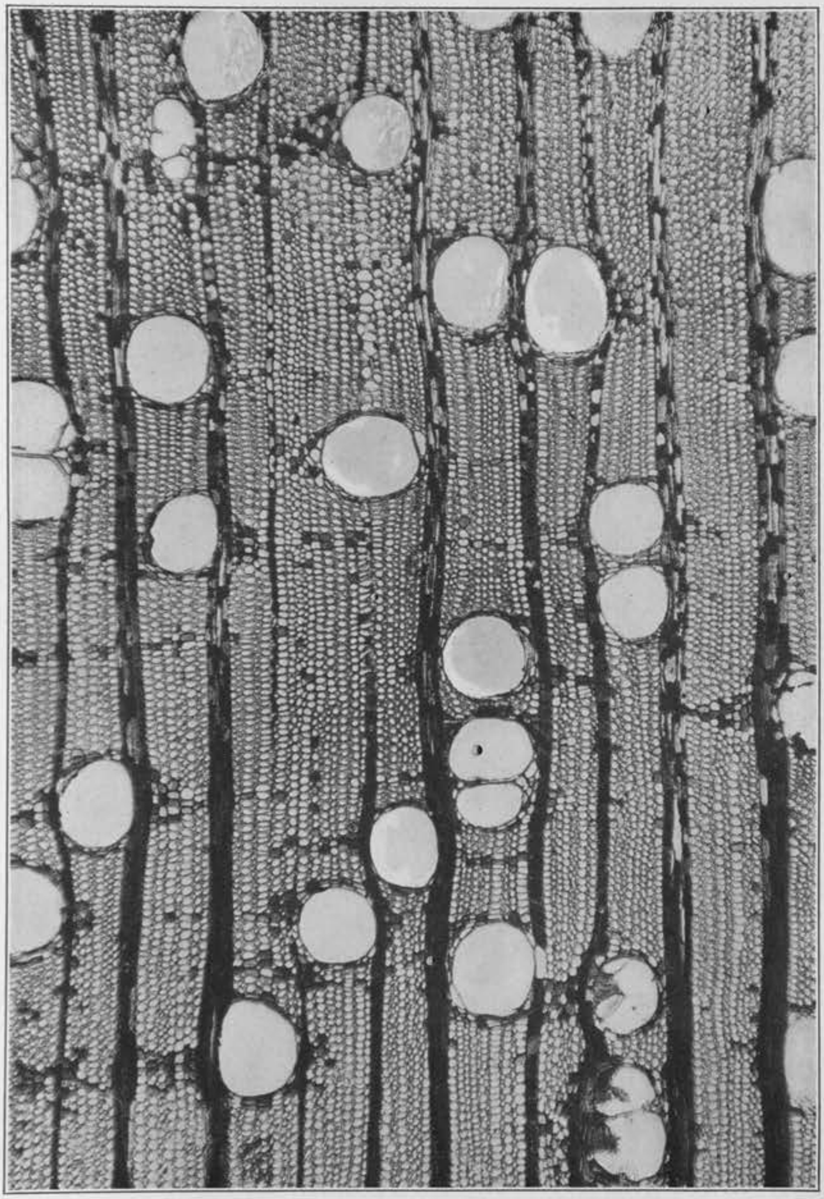

PLATE 17. CROSS SECTION OF WOOD OF SHOREA TEYSMANNIANA, × 50.

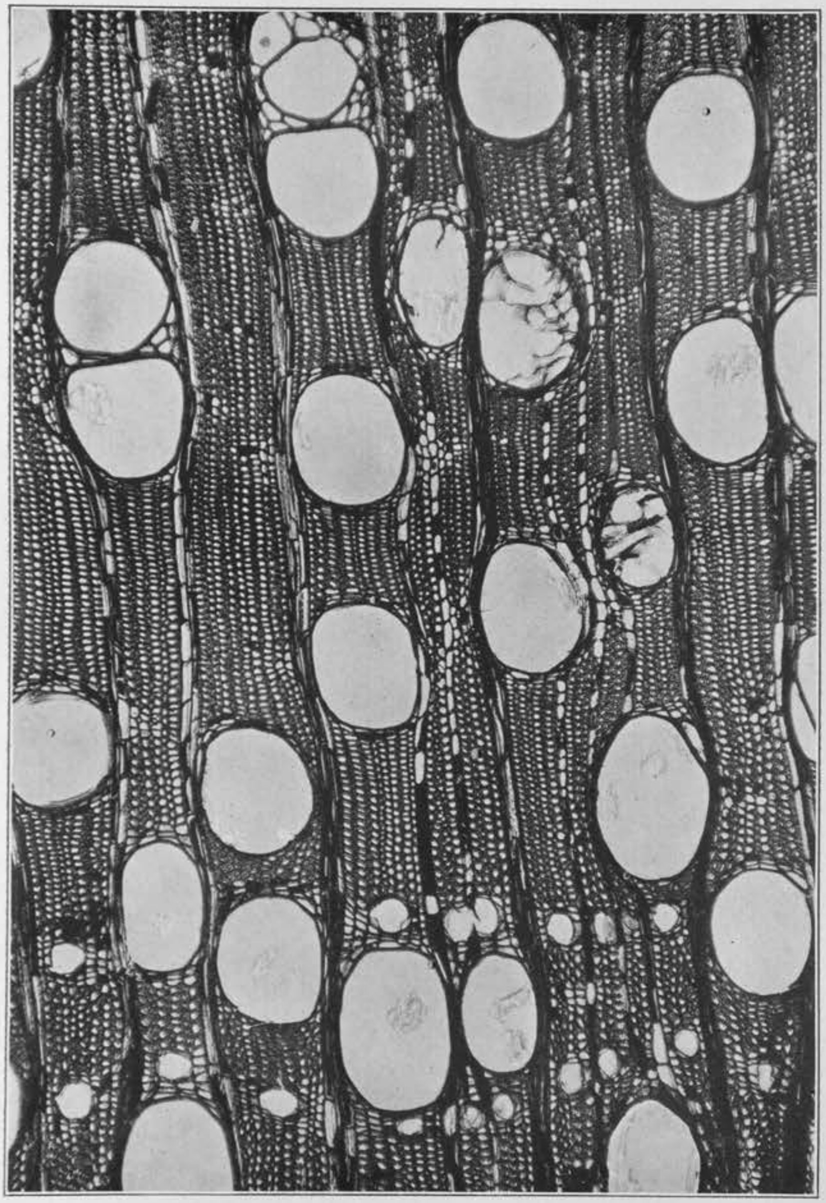

PLATE 18. CROSS SECTION OF WOOD OF SHOREA NEGROSENSIS, × 50.

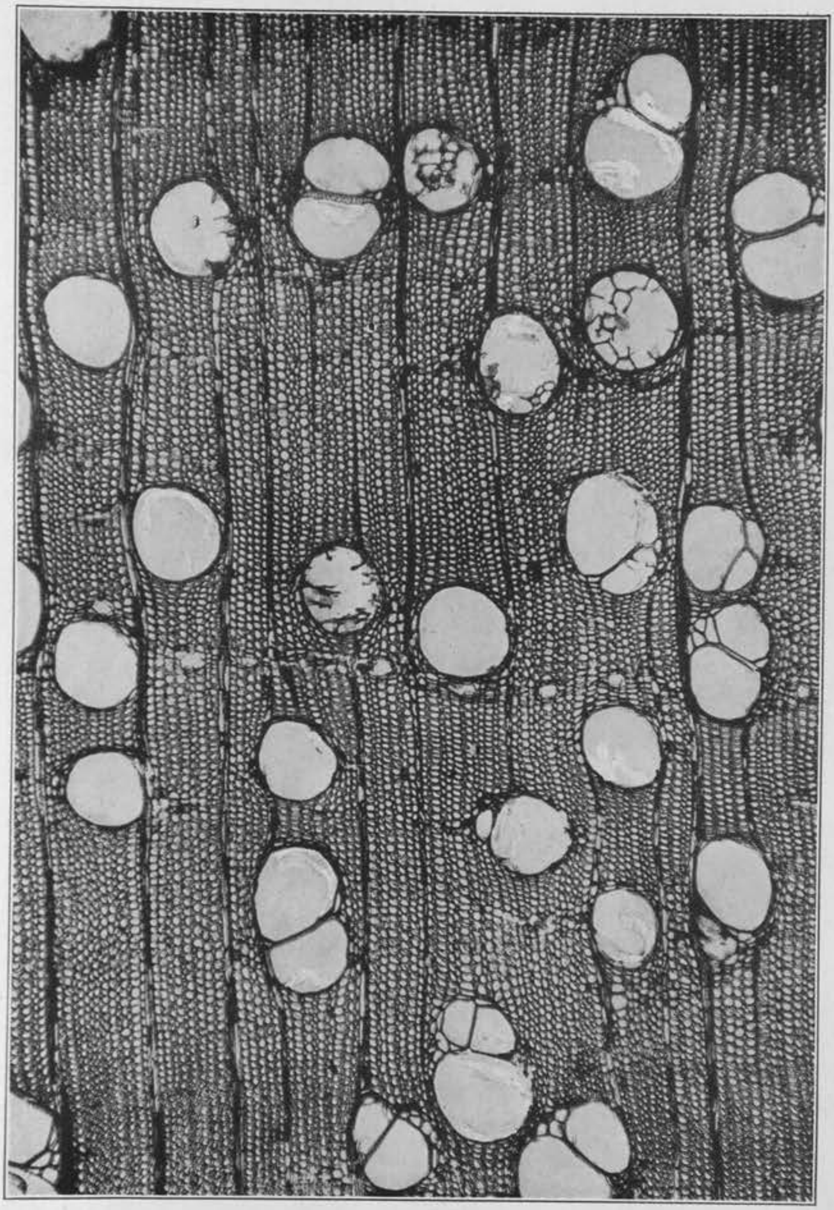

PLATE 19. CROSS SECTION OF WOOD OF SHOREA POLYSPERMA, FROM NEGROS, × 50.

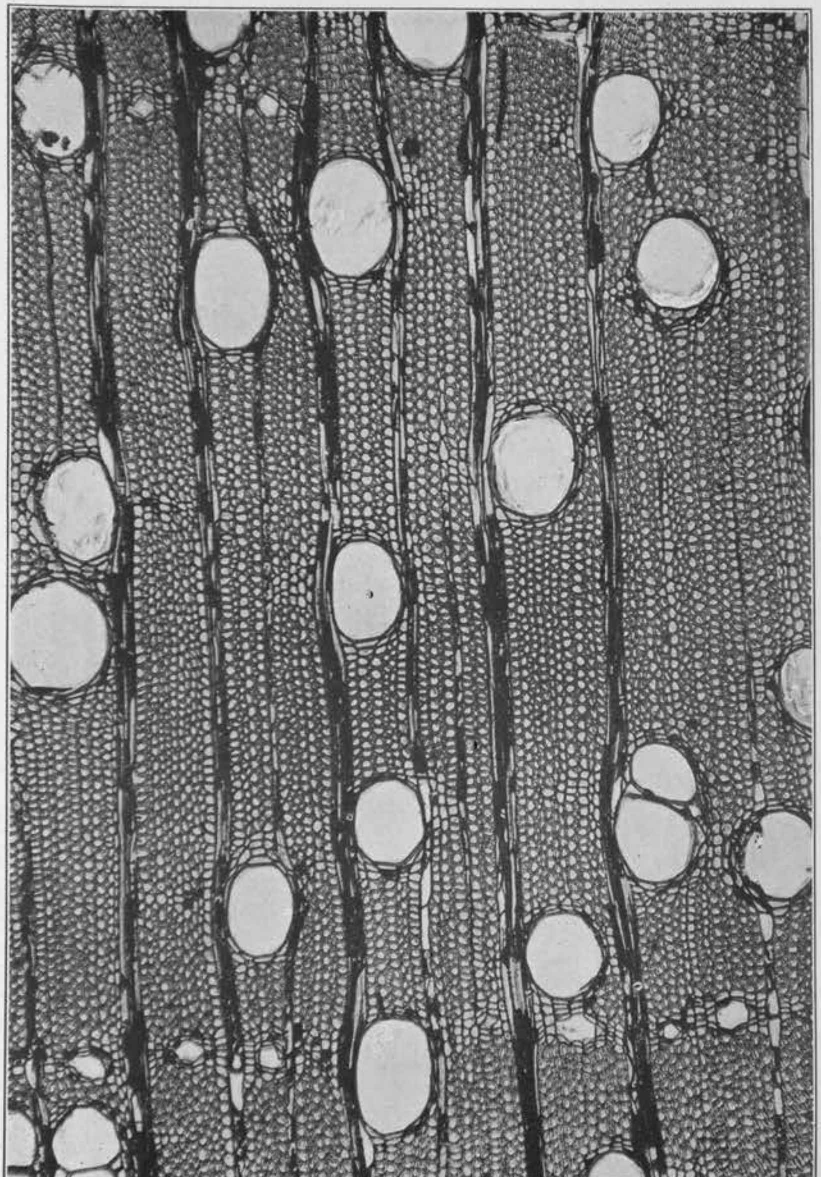

PLATE 20. CROSS SECTION OF WOOD OF SHOREA POLYSPERMA, FROM BATAAN, × 50.

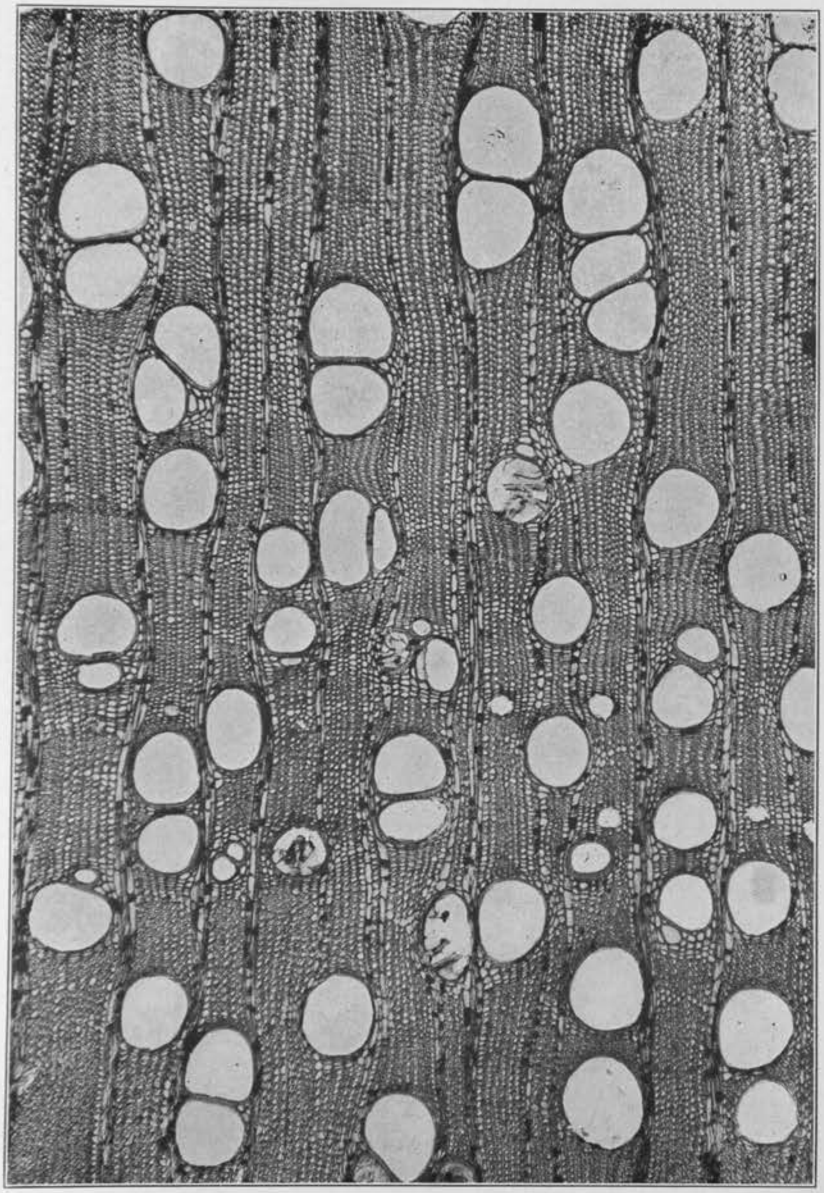

PLATE 21. CROSS SECTION OF WOOD OF SHOREA MINDANENSIS, × 50.

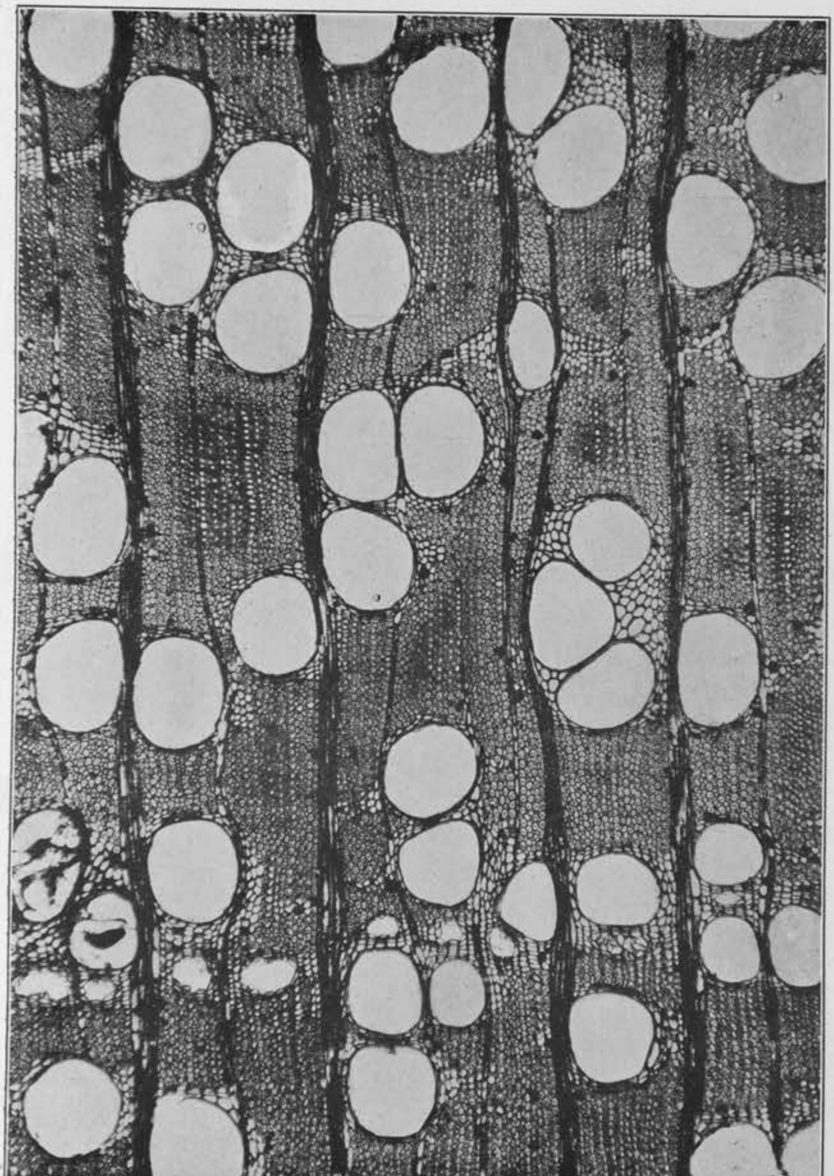

PLATE 22. CROSS SECTION OF WOOD OF PARASHOREA MALAANONAN, × 50.

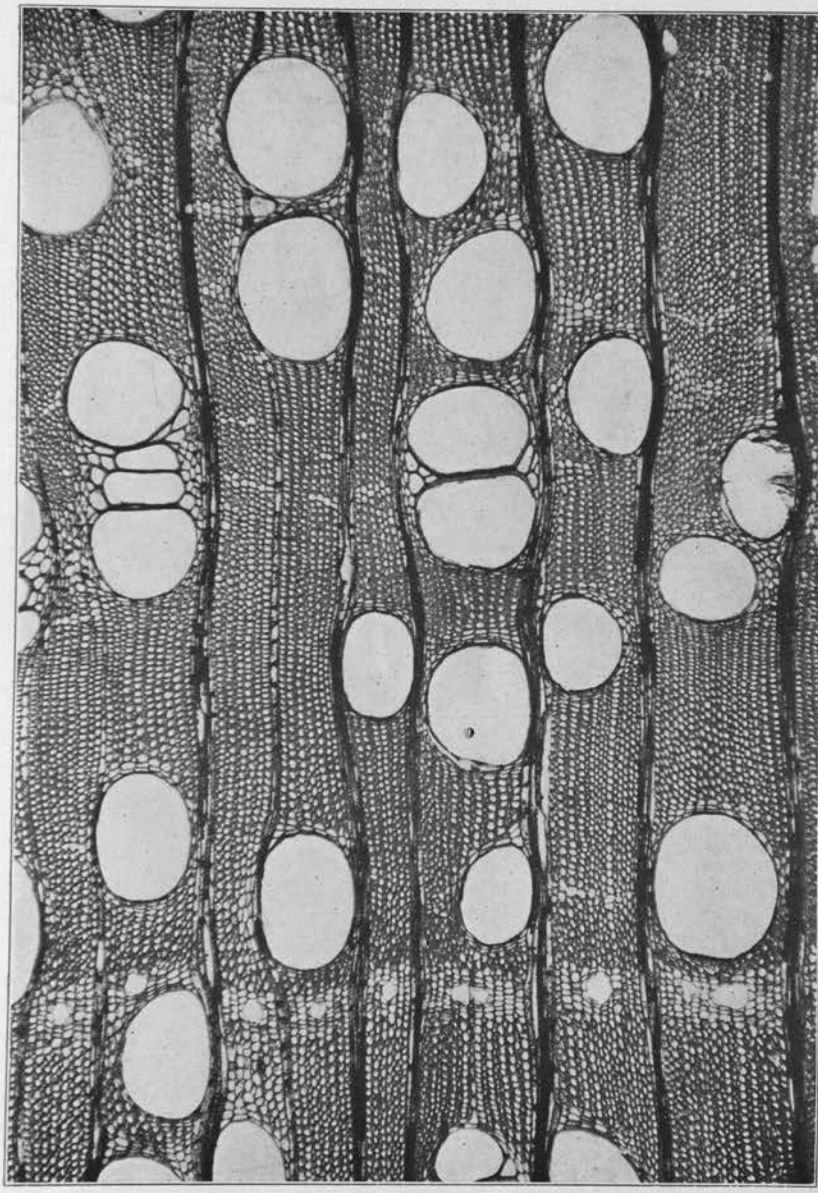

PLATE 23. CROSS SECTION OF WOOD OF SHOREA EXIMIA, × 50.

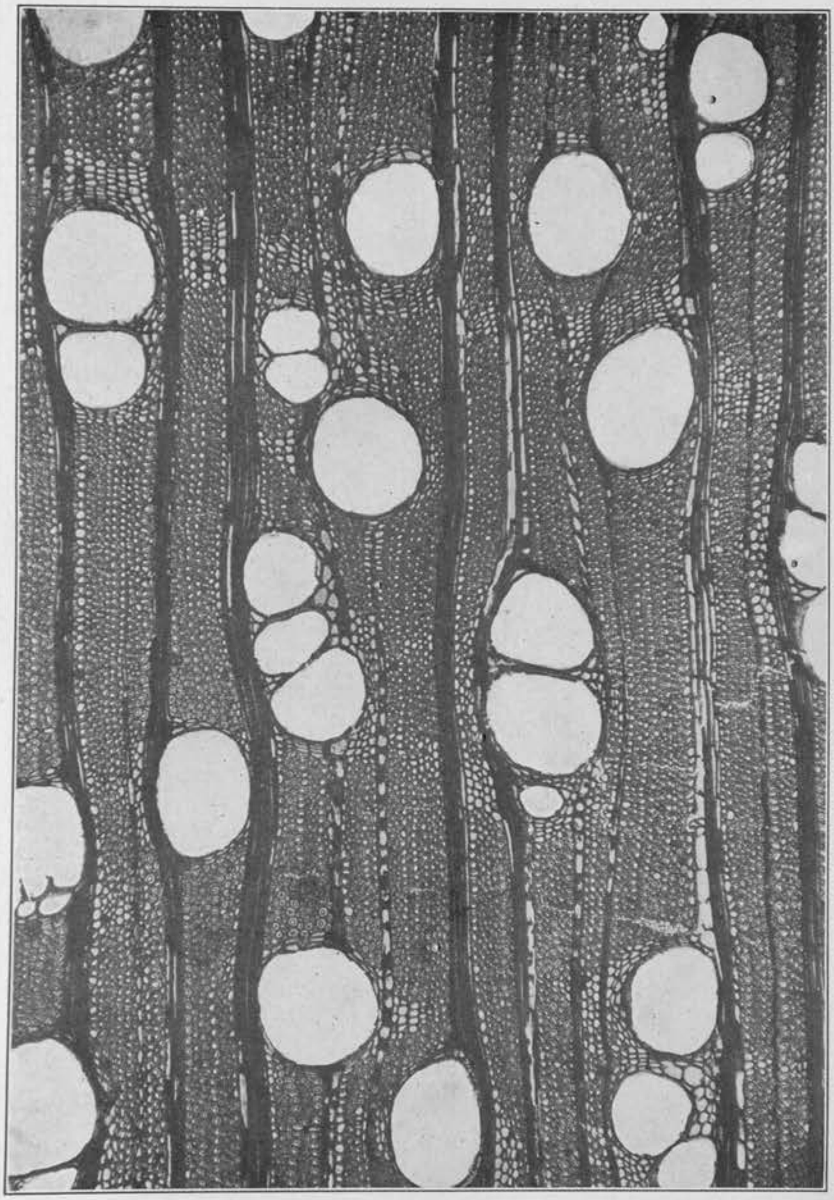

PLATE 24. CROSS SECTION OF WOOD OF PENTACME MINDANENSIS, × 50.

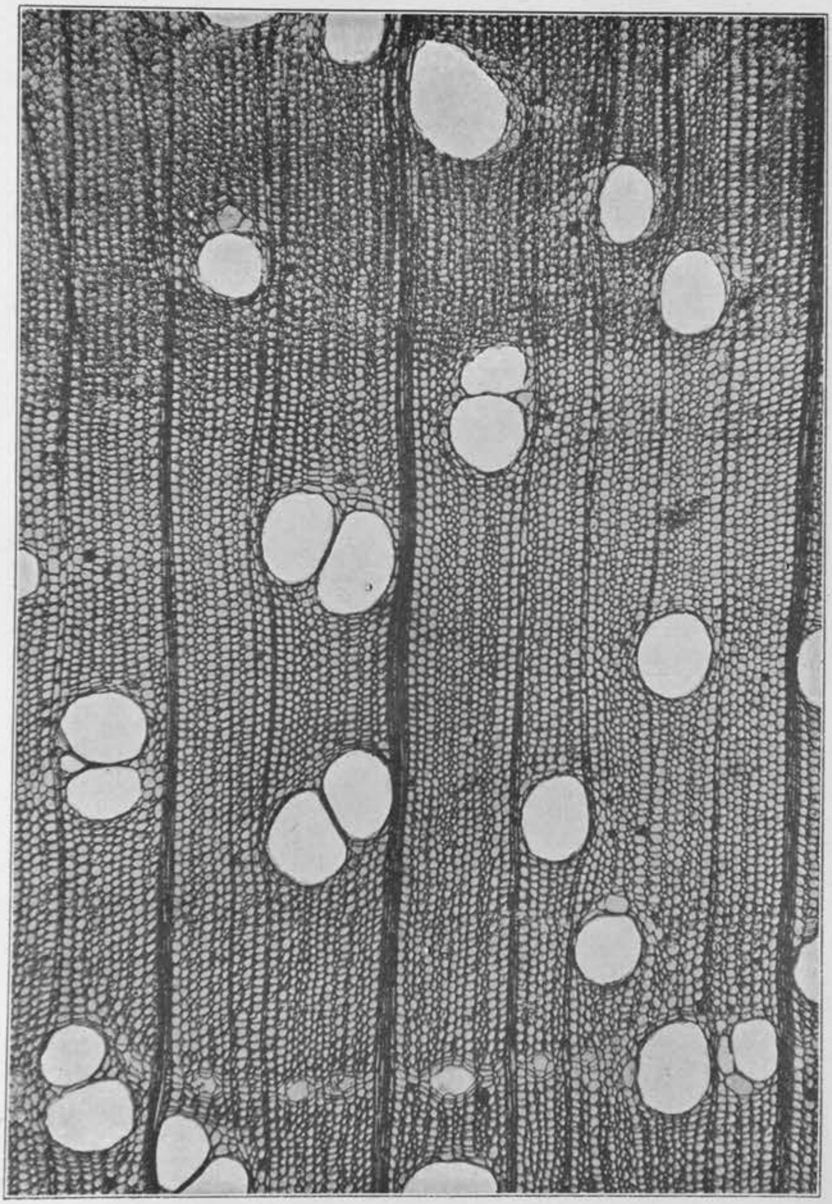

PLATE 25. CROSS SECTION OF WOOD OF PENTACME CONTORTA, × 50.

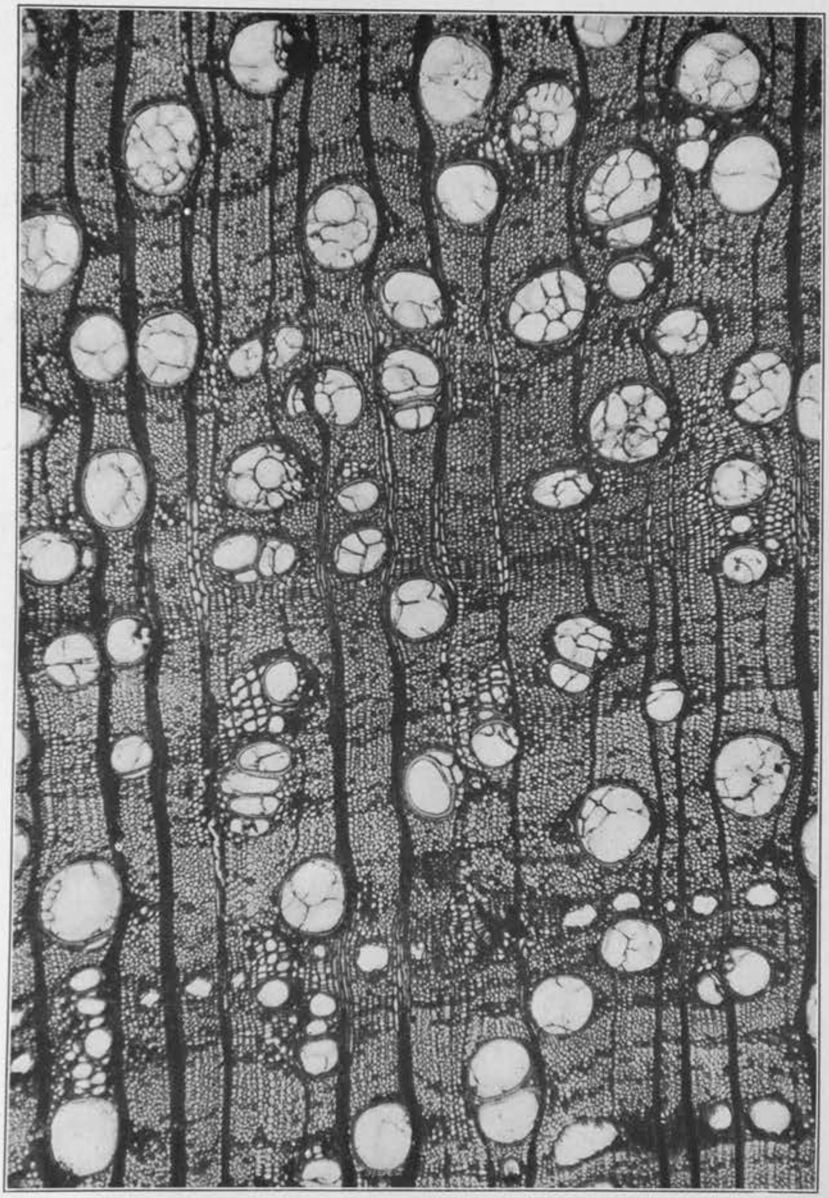

PLATE 26. CROSS SECTION OF WOOD OF ISOPTERA BORNEENSIS, × 50.

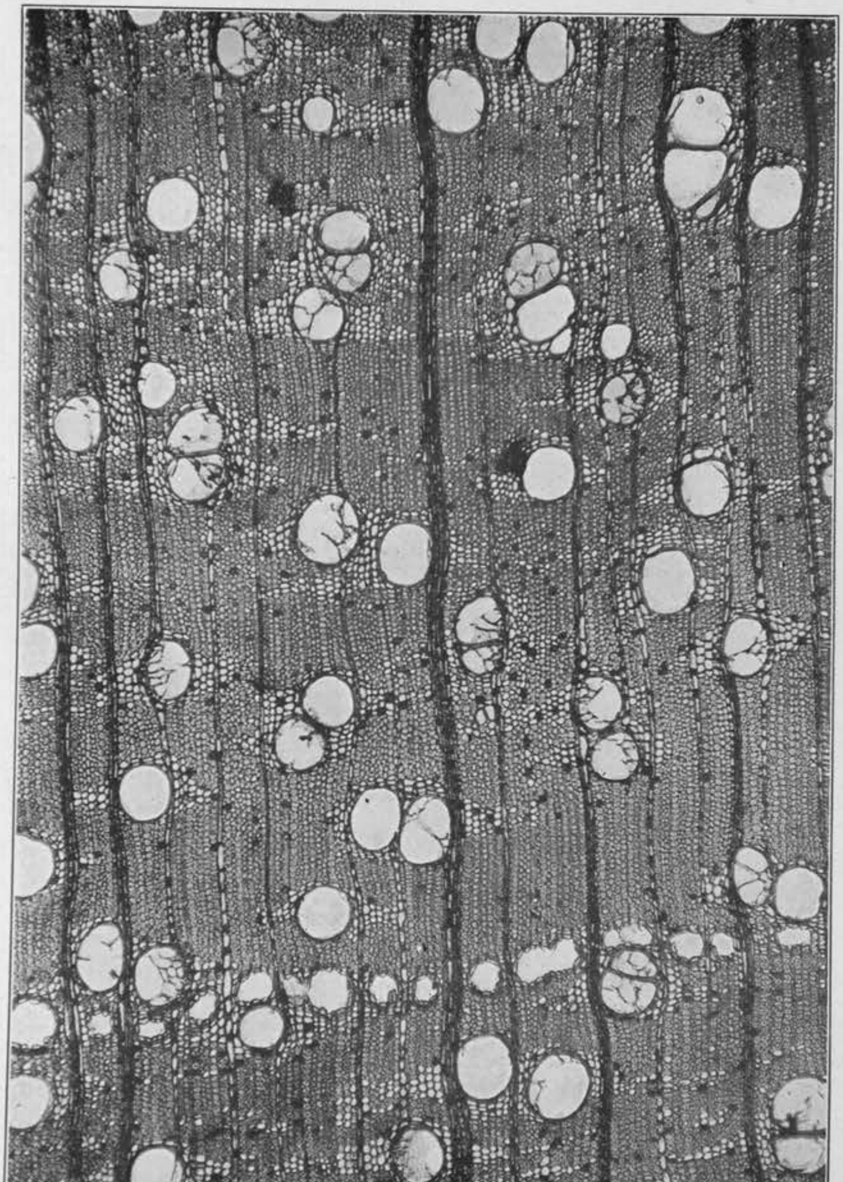

PLATE 27. CROSS SECTION OF WOOD OF SHOREA BALANGERAN, × 50.

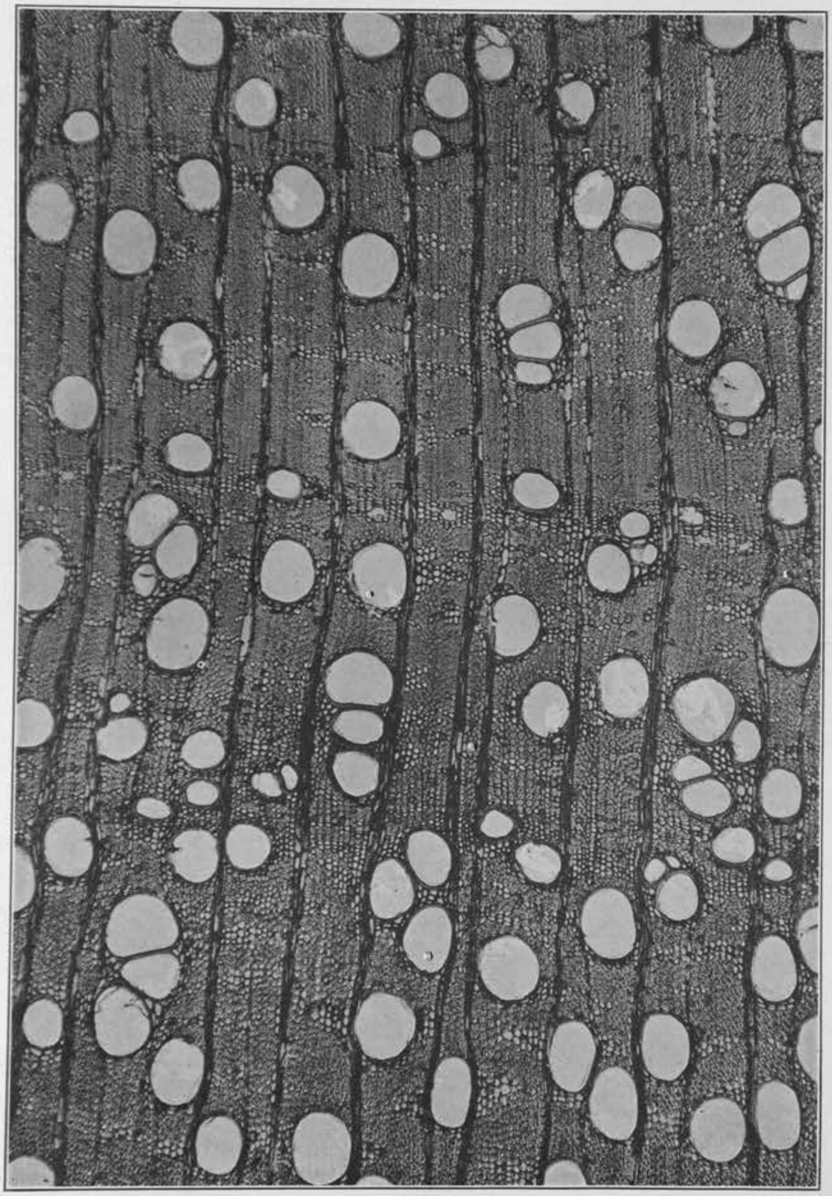

PLATE 28. CROSS SECTION OF WOOD OF SHOREA GUISO, × 50.

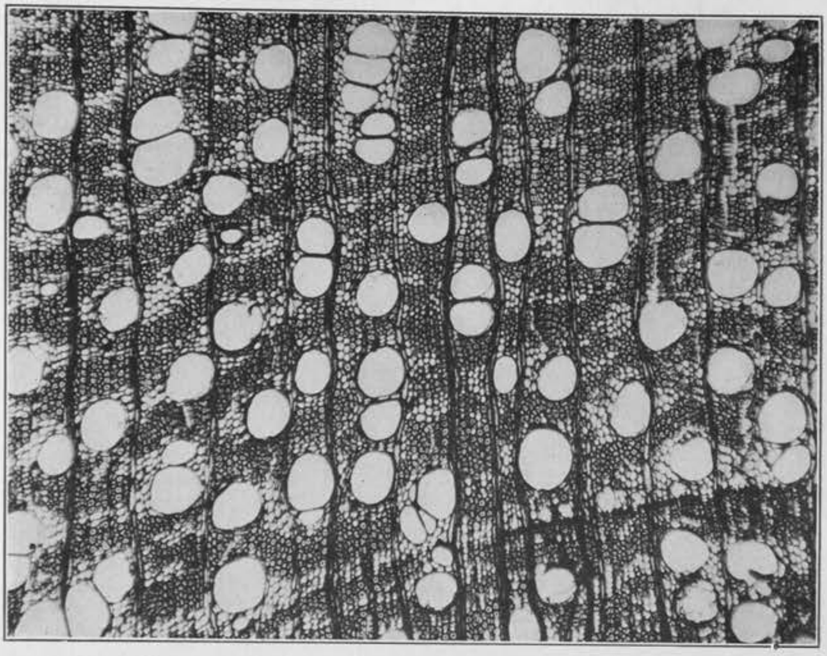

Fig. 1. Cross section of wood of Balanocarpus cagayanensis, × 50.

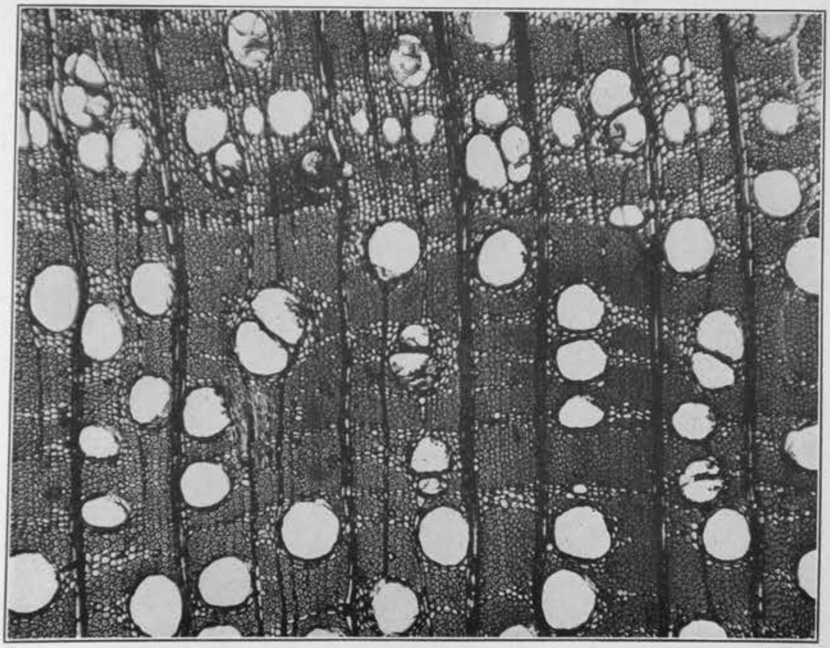

Fig. 2. Cross section of wood of Hopea mindanensis, × 50.

PLATE 29.

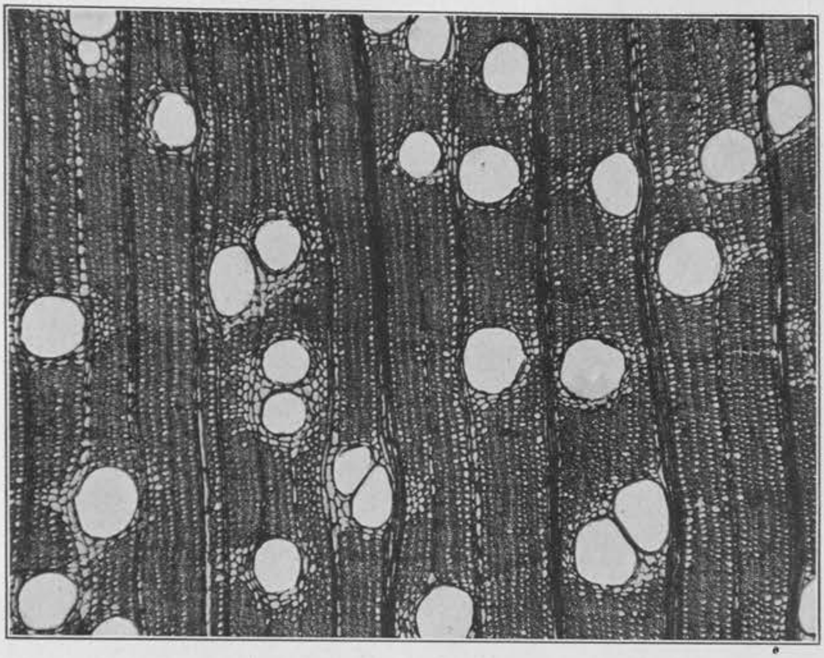

Fig 1. Cross section of wood of Hopea acuminata, × 50.

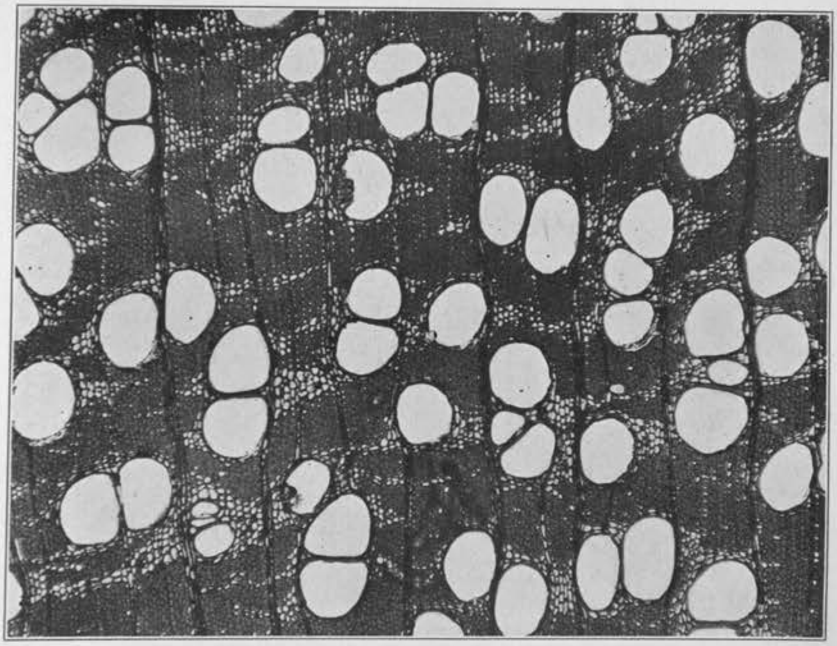

Fig. 2. Cross section of wood of Hopea philippinensis, × 50.

PLATE 30.

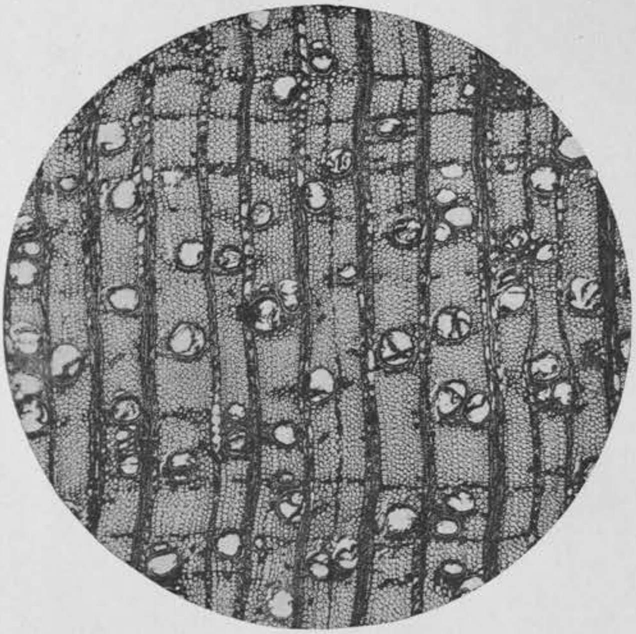

Fig. 1. Cross section of wood of Hopea pierrei, × 50.

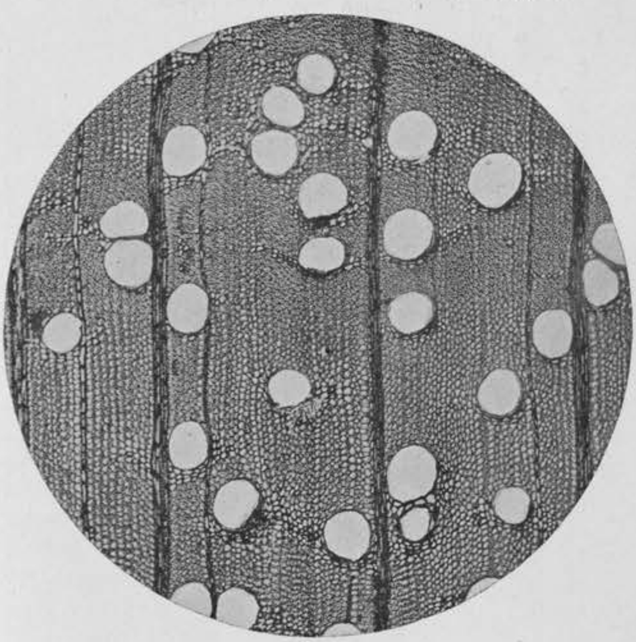

Fig 2. Cross section of wood of Hopea plagata, × 50.

PLATE 31.